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THE MODERN MARINE ENGINE, BOILERS, ETC.

A SERIES OF LECTURES DELIVERED AT THE NAVAL WAR COLLEGE, NEWPORT, R. I., SEPTEMBER, 1894.

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LECTURE I.—THE MODERN MARINE ENGINE.

In beginning this second course of lectures on Marine Engineering before the Naval War College I feel that just a word should be said in explanation of the line which has been adopted, and to anticipate the comparisons which will naturally be made with the work of my predecessor, Passed Assistant Engineer Hollis, now Professor of Engineering in Harvard University. In addition to his brilliant attainments as an engineer, Professor Hollis had the advantage of being the first to deliver this course of lectures, so that he was able to present matter not only valuable but highly original; and as he has already covered the field pretty thoroughly, it will be practically impossible for me to do as he did and give you anything entirely new. I shall attempt

merely to give a résumé of existing conditions, with some observations intended to give clearer ideas as to the way in which existing conditions have come about, and with some suggestions with regard to the machinery of our naval vessels, which, it is believed, will be for the good of the service generally.

It is now scarcely more than ten years since the beginnings of what we generally call "The New Navy" were laid, as the designs for the *Chicago*, *Boston*, *Atlanta* and *Dolphin* were made about 1883, and it is a still shorter period since the first triple-expansion engine was placed in one of our naval vessels—the *Vesuvius*—in December, 1888, followed shortly after by the trial of the *Yorktown* in February, 1889.

The history of the progress of what may be called multiple expansion is very interesting as showing how, in the early days, conservatism rendered progress very slow; but as experience had been gained in the first step from simple to compound engines, when the time came for a further advance it was made with very little hesitation. When the compound engine was introduced on a practical scale about twenty-five years ago, many engineers of great ability contended that it was simply a fad of certain firms, and that single-cylinder engines with the same degree of expansion would run just as successfully and economically. So strong was this idea that many firms continued to build simple engines long after the success of the compound engine had been thoroughly demonstrated, and one steamship line even went so far as to engine two identical ships with the two kinds of machinery to determine by a crucial test whether the compound engine really was the necessity that others claimed. This experiment showed very conclusively that the expansion by separate stages, instead of in one cylinder, had marked practical advantages for marine purposes, as it was found to be impossible to keep the simple engines in repair and efficient, while the compound engines gave no trouble from the start.

The economy of the compound engine over the simple was marked from the very beginning, and as improved materials and better workmanship enabled higher pressures to be used, more and more benefit was derived from higher pressures with in-

creased ratios of expansion, until the compound engine may be said to have reached its highest perfection in the transatlantic greyhounds *Arizona*, *Alaska* and *Oregon*.

Shortly before the building of the *Oregon*, the vessel had appeared the success of whose machinery was to revolutionize the type of engine, or perhaps it might be better expressed as the next natural step in its evolution. The steamer *Aberdeen* was built in 1881 by Messrs. Napier & Sons, of Glasgow, and contained the first triple-expansion engine of large size whose success was unquestionable. Dr. A. C. Kirk, the managing director of this firm, had placed triple-expansion engines on vessels at an earlier date, and as far as the engines themselves were concerned there had been no trouble; but owing to the difficulty of procuring a suitable boiler at these earlier dates to carry the high pressures needed for the success of the triple-expansion engine, the early efforts were not entirely successful. The *Aberdeen*, however; was successful from the very start, and was followed in a very short time by numerous other engines of this type.

War ship designers were naturally interested in this improved type of engine, but the first application was made by Dr. Kirk's firm, Messrs. R. Napier & Sons, in the English belted cruisers *Australia* and *Galatea*. When these vessels were originally tendered for they were to have three-cylinder compound engines; but his experience with the triple-expansion engines in merchant vessels led Dr. Kirk to be willing to guarantee a somewhat greater horse power for the same weight if permitted to use triple-expansion engines. Permission was granted to use engines of this type, and the vessels finally made their steam trials in 1887 and were very successful. Since that date there has hardly been a war vessel designed anywhere in the world which has not used triple-expansion engines, so that the compound engine is to-day as much out of date as the simple engine was, compared with the compound, fifteen or twenty years ago.

A question will naturally arise at once as to the reasons for the steady increase of steam pressure and range of expansion, and the answer may be put quite briefly,—that the change has been made almost solely for economy as far as the engines are

concerned, and for reduction of boiler weights consequent upon the smaller weight of steam required per horse power in the engines. Of course, an increase of steam pressure could be made to give much lighter engines, just as locomotive engines, or non-condensing stationary engines with high pressure steam would be much lighter than condensing engines using a considerable degree of expansion; but as a matter of fact, in almost the same proportion as the initial pressure has been increased so has the ratio of expansion, so that, speaking roughly, we may say that as far as the steam pressure is concerned the weight of engines has not materially changed in the last five or six years.

The reduction in coal expenditure is very decided. With the simple engine working under conditions of maximum efficiency and with steam of about 25 or 30 pounds pressure the coal per horse power was 3¼ pounds. The early compound engines using steam of 60 pounds pressure required 2¾ pounds per horse power. The compound engine at its most advanced state required 2.3 pounds, while the triple-expansion engine with steam of 160 pounds, when working under favorable conditions, gets a horse power for 1.8 to 2.0 pounds, and under specially favorable conditions of engine and boiler as well has gone as low as 1.5 pounds, and quadruple-expansion engines carrying steam of 250 pounds pressure have given results as low as 1¼ pounds.

The effect of this increase of economy in coal expenditure has been very marked, and it is entirely safe to say that but for the great reduction in coal consumption the mastless cruisers of to-day would be an impossibility.

It has been already remarked that the change from simple to compound engines was very slow, while the change from the compound to triple and quadruple-expansion engines has been comparatively rapid, and it was intimated that this more recent change came about more rapidly largely because of the experience in the previous ones. Another reason which undoubtedly had great weight is the great improvement in the materials at the disposal of the designer in this more recent period. Up to about 1878 it may be said that we were still in the iron age as regards the material of marine machinery. Mild steel had been

slowly coming into use and had been used in some cases before that date; but it was about that time that the extended use of mild steel for boiler plates, and also for shafting and the moving parts of engines came about. With wrought iron there was always more or less uncertainty in thick plates of their absolute homogeneity and freedom from lamination and other defects, and the steam pressure was practically limited to some 60 or 80 pounds on account of the impossibility of procuring plates of the necessary thickness and reliability for the higher pressures. When the steel makers had gained sufficient experience to insure the reliability of thick plates the pressures for compound engines immediately went up to as high as 120 pounds, and as the manufacture has been steadily improved, when the demand came for pressures from 150 to 180 pounds for the triple-expansion engines, the steel makers were ready to answer the demand, and consequently there was practically no delay in the transition from compound to triple-expansion engines. The same thing holds true of the material for shafting, piston rods, connecting rods, valve stems, etc., which are now almost universally made of steel, which has both a greater strength and greater reliability than the wrought iron which it has displaced.

It should be remarked in this connection that, like so many other improvements, high pressures are not an unmixed blessing. Much greater care has to be used in making all the joints in steam piping and around the boilers and cylinders, and it is more difficult to keep these joints tight. A leak which with lower pressure steam would have amounted to nothing becomes quite troublesome with these higher pressures, and the simple means which often avail for a temporary repair with the lower pressures will rarely answer for the higher ones. The benefit of the higher pressures, however, is so great that these disadvantages are accepted very cheerfully.

Every officer of the service who has kept himself at all posted in the recent history of machinery design is aware that within the last fifteen years the great problem for the designer of machinery has been to secure great power on comparatively little weight. I have prepared a table showing the weights of various types of

machinery, together with some other information about their performance, which will be interesting, and from this table it will be very apparent that there was a tremendous advance from what might be called the old fashioned heavy machinery to modern light machinery, as typified in some of the later compound engines. It has already been remarked that increase of steam pressure of itself has not made very much difference in the weight of the engine, on account of the fact that the increase of pressure has been accompanied by an increase in ratio of expansion, so that the equivalent mean pressure referred to the low pressure cylinder is not greatly different from what it was with the lower pressures; but the reduction of weight has come about at the same time as the increase of pressure, and it is therefore natural that the cause of the reduction of weight of engines should be sought.

There are three chief causes for this reduction of weight: Increased speeds of rotation, improved material and workmanship, and improved design.

The first of these items, increased speed of rotation, is often expressed as increased piston speed, but it must be noted that high piston speed may consist of a long-stroke engine making few revolutions, or a short-stroke engine making a great many, and a very little consideration will show that if the increased piston speed comes about simply by increasing the stroke there will be no reduction of weight, because the cylinders themselves will be increased in size as well as every other part of the engine connected with them, while the short-stroke engine with rapid speed of rotation keeps down the size of cylinders and of all other parts of the engine, and, therefore, materially reduces the weight. The table to which I have referred illustrates this point very thoroughly, as it will be noticed that the *Wampanoag* had a speed of rotation of only 31 revolutions per minute, the *Trenton* of 54 revolutions, while the *Charleston* jumps to 114 revolutions, and the large triple-expansion engines run about the same or a little higher, while the *Vesuvius* makes 270 revolutions and the *Cushing* 370 revolutions per minute, about ten times as many

TABLE SHOWING PROGRESS IN MARI

Name.	Steam Pressure.	Air Pressure.	Revolutions.	Displacement. *a* = normal. *b* = deep load draught.	Weights.						Speed.
					Engine Room.	Fire Room.	Total Machinery.	Coal. *a* = normal. *b* = bunker capacity.	Machinery and Coal. *a*=normal. *b* = deep load.	Per cent. displacement in machinery and coal. *a* = normal. *b*= deep load.	
Pensacola	30	nat. draft.	32	3,000	*Tons.* 185	*Tons.* 163	*Tons.* 348	*Tons.* 312	*Tons.* 660	*Per cent.* 22 0	*Knots.* 9 0
Wampanoag.....	32	nat. draft.	31	4,370	612	638	1,250	750	2,000	46.0	16.8
Charleston..... *a*	91	$1\frac{3}{4}$	114	3.730	337	395	732	328	1,060	28.4	18.2
b	...	...	...	4.481	...	.....	.....	760	1,492	33.3	...
San Francisco.. *a*	135	2	125	4.088	433	481	914	350	1,264	31 0	19 52
b	...	...	...	4.666	...	.....	.....	628	1,542	33.2	...
Olympia..... *a*	166	2	139	5.570	507	732	1.239	400	1,639	29 5	21 7
b	..	...	...	6,588	...	.....	.....	1,093	2,332	35 4	...
Minneapolis..... *a*	165	1	133	7,350	694	1,226	1,920	750	2,670	36.2	23.0
b	...	...	...	9,054	...	.....	.....	1,700	3,620	40.0	...
Vesuvius..... *a*	155	2	270	771	79 5	170	249 5	25	274 5	35.6	21.4
b	...	...	...	965	...	.....	.....	152	401.5	41 6	...
Cushing ..... *a*	250	3	370	105	24 5	30	54.5	10	64 5	61 4	22.5
b	...	...	...	137	...	.....	.....	30	84 5	61.7	...

* Superheated steam used. † Coil boilers.

machinery and coal. a = normal. b = deep load.	Trial Trip Performance.					Moderate Speed.					Weight of engines per I.H.P. full power.	Weight of boilers per I.H.P. full power.
	Speed.	I.H.P.	Coal per I.H.P.	Coal per day for all purposes.	Radius of action.	Speed.	I.H.P.	Coal per I.H.P.	Coal per day for all purposes.	Radius of action.		
cent.	*Knots.*		*Lbs*	*Tons*	*Knots.*	*Knots.*		*Lbs.*	*Tons.*	*Knots.*	*Pounds.*	*Pounds.*
2 0	9 0	1,161	3 55	44 5	1.520	7 00	550	3.50	21.0	2,500	356.9	314 5
6.0	16.8	4,049	3.15	138	2,190	11 4	1,275	2 75[a]	38.0	5,400	338.6	352 9
8.4	18.2	6,666	3 0	216	665	...	...	...	.....	...	113 2	132 7
8 3	...	.....	...	.....	...	10 5	1.200	3.25	45.0	4.275	.....	.....
1 0	19 52	9.717	2.4	250	655	...	...	...	.....	...	99.8	110 9
3.2	...	.....	...	.....	...	10.5	1,250	2.40	35.0	4 462	.....	.....
9 5	21 7	17.313	2 3	428	485	...	...	...	.....	...	65.6	94 7
5 4	...	.....	...	.....	...	12 0	1,850	2.40	52.5	6,000	.....	.....
6.2	23.0	21,000	2 3	520	795	...	...	...	.....	...	74.0	130.8
0 0	...	.....	...	.....	...	13 0	2 725	2 30	72 0	7.370	.....	.....
5.6	21.4	3 795	2.3	95	135	...	...	...	.....	...	46.9	100.3
1 6	...	.....	...	.....	...	13 0	975	2.35	25 0	1,900	.....	.....
1 4	22.5	1.760	2 0	37 5	143	...	...	...	.....	...	31.2	38.2†
1.7	...	.....	...	.....	...	13 0	150	2.00	3.3	2.840	.....	.....

† Coil boilers.

as the *Wampanoag*, seven times as many as the *Trenton*, and three times as many as the later large engines.

Improved materials have also played a most important part in the reduction of weight of both engines and boilers, because the steel used for boiler shells is about 30 per cent. stronger than the wrought iron which preceded, while the steel for shafting, piston rods and connecting rods is from 25 to 40 per cent. stronger. Steel castings have also come in within the last few years, which now take the place in many cases of cast iron, with a strength at least three times as great, thereby enabling a material reduction of weight, although not in exactly the same ratio. Steel forgings, too, have in many parts displaced cast iron, notably in the engine framing, with great reduction of weight. This is especially true in very light, high-speed machinery.

It is also to be noted that the improved materials not only allow of reduction of weight by their own increase of strength, but much lower factors of safety are employed than formerly obtained, because the material is naturally very much more reliable, and we have also, since the change from the iron to the steel age, introduced methods of inspection which give absolute confidence in the material we are using. In the old days it was usually the custom to purchase material from reliable makers and assume that it was all right and had a certain strength. At the present time we assume nothing, but test everything and so know exactly what we are doing.

In my first acquaintance with the designs for naval boilers, some fifteen years ago, a factor of safety as great as 8 was used in figuring the strength of boiler shells. At the present time a factor of safety greater than $4\frac{1}{2}$ is never used for naval boilers, and sometimes it is as low as 4. A similar reduction of the factor of safety holds for all those portions of the machinery where we are able to assure ourselves absolutely of the quality and strength of the material.

There still remain, however, some portions of the machinery, notably the cylinders and valve chests, which, from their complexity, have to be made of cast iron; and while there have been improvements in moulding and in the quality of the material,

they have not been very marked, and in these there has been practically no reduction of weight.

With regard to improved design may be mentioned the fact that, with the wrought-iron boilers and lower pressures, the form of riveted joint employed was assumed to have a strength of about 65 per cent., while the modern treble-riveted joints used with the higher pressures have a strength as high as 85 per cent. The forms of strong furnaces used have also had a great effect, because it would have been practically impossible to carry the high pressures now prevailing with the forms of furnaces which obtained twenty or twenty-five years ago. Corrugated and ribbed furnaces made of welded tubes enable us to use sheets thin enough not to be injured by the heat, while still strong enough to withstand very high pressures.

The use of independent condensers made of composition, instead of the older form of cast-iron ones designed, with the pumps and channelways, as part of the engine framing, has caused a great reduction of weight.

Coming under this head of improved design may also be included forced draft for the boilers. This has caused a decided reduction of weight in a part of the machinery which would have been enormously heavy for the high powers now demanded. In fact, it is safe to say that but for forced draft it would not have been possible to place the powers in our ships which are now common. The reduction of weight due to forced draft depends, of course, on the extent to which it is carried. In our larger ships, where the effect has been to burn somewhat more than twice the amount of coal which could be burned with natural draft, the reduction of weight has probably been nearly 50 per cent. This question of forced draft will be treated more fully in a later lecture.

Also coming under this head may be mentioned the use of tubulous or coil boilers, which of themselves, without the use of forced draft, would effect a reduction of about 50 per cent. in the weight of boilers as compared with cylindrical boilers of the usual type. This subject also will be considered in a later lecture.

Emphasis has been laid upon the fact that the reduction in weight of engines is due almost entirely to increased speed of rotation, and the table which has been given shows what a great reduction in weight per horse power we find when we compare the weight of a torpedo-boat engine with an ordinary high-speed engine, but of larger size. The question then naturally arises, Why not adopt these small, very fast-running engines for all ships? There are some who believe that this can be done, and at the meeting of the Society of Naval Architects and Marine Engineers last year a paper was presented in which the author maintained that very fast-running engines should be used even on the largest vessels. It may be stated confidently that the universal consensus of opinion of competent engineers is against any such idea as this, although it is perhaps difficult to show in a brief way why this is so. One very strong argument, however, at once presents itself in the fact that there is a tremendous demand for reduction of weight not only in war vessels but in merchantmen, and that the brightest minds in the profession are constantly considering every legitimate means of securing this end. They are perfectly aware of the benefit of high rotational speeds, and the fact that they do not adopt them shows of itself that there must be very good reasons. One reason which may be given is this: It is quite evident that fast-running engines are only adapted to drive small propellers, and that there is manifestly a point at which the propeller would become too small to drive the ship at all, and another point considerably higher where the propeller would be too small to drive the ship efficiently. The consequence is that there is a rough relation between the size of the ship and the size of the propeller; and, as the proportions of propeller require for a given diameter a pitch within certain limits, this of itself would set the speed for the engines. Another reason is that the wear and tear of very fast-running machinery is much greater than on machinery running at a slower speed, and that very much greater care and vigilance is required in the attendance bestowed upon it to insure its integrity. In the old fashioned, slow-running engines a heated bearing was a very common occurrence, and its growth was comparatively

slow, so that remedial measures could be applied in time. With modern high-speed machinery much greater care is taken to guard against heated bearings; but should one occur, its growth would be so rapid that unless the attendants were very numerous, seizing would soon occur, with a consequent stoppage of the machinery.

A very interesting point in this connection is the experience of Mr. C. D. Mosher, the designer of the phenomenally fast steam yachts *Norwood* and *Feiseen*. These are small boats with a displacement not much greater than some of our steam launches, while the power is very much greater, and the speed runs up to nearly 30 statute miles an hour. In a recent conversation Mr. Mosher informed the writer that he personally inspected the manufacture of every piece of the engine of these boats and required workmanship to the highest degree of perfection. All shaft journals he required to be absolutely cylindrical, with the maximum permissible error half a thousandth of an inch. Then, too, in fitting the pistons to the cylinders he is not content with simply having good workmanship in the lathe and boring-mill, but after the cylinders have been bored out he has them scraped accurately while cold, then heated up to about the temperature they would have when steam is on, and again scraped to absolute truth. This same process is carried out in every part of the machinery. While such minute accuracy is possible and permissible for small machinery and unlimited funds, it would manifestly be impossible for machinery of the size that would have to be used in our large vessels, even if very high rotational speeds were adopted. Mr. Mosher also speaks of the process of getting one of these engines ready for a trial as "tuning up," a most expressive term which conveys its own moral. Whenever his boats go out to make a record he goes in charge of the machinery himself.

In one sense modern machinery is more complicated than the older style which it has replaced, while in another it is simpler. We have entirely abandoned the ingenious variable cut offs which were a prominent feature of the later compound engines, and depend now for varying the cut off upon the position of the

link, or the equivalent in what are known as the radial valve gears. The considerable range of expansion provided by the difference in size of cylinders themselves would give a fair degree of economy, even if the same cut off were maintained in the high pressure cylinder; but by linking up, as it is called, the ratio of expansion can be considerably increased, and all the complication of the special cut-off gears is avoided.

The main engine itself is also simpler than the old one from the fact that in the process of evolution it has gradually been relieved of all work except that of turning the propeller, all the pumps being driven independently. The plan of making the condenser and all its pumps entirely independent of the main engine has a great many manifest advantages. The condenser can then be made of such a shape as to reduce its weight very decidedly, and the connections to the pumps are very much simpler than in the older form where there were tortuous passages in an already complicated casting, while the independence of the pumps enables a vacuum to be obtained before the main engines are started, thereby rendering their handling much easier; and they can also be adjusted to meet the work coming directly upon them, which sometimes varies independently of the regimen of the main engines. The plan of rendering the condenser and pumps wholly independent of the engine does not, however, meet with universal approval, and at the Engineering Congress, which was held in Chicago last summer, Mr. Dickie, the talented manager of the Union Iron Works, presented a paper on auxiliary machinery, in which he made out a very strong case for the desirability of making the condenser an integral part of the design of the main engine and driving the air pump from the main engine. In another lecture in which the question of the economy of auxiliaries will be taken up, the advantage which would accrue from the point of economy in thus driving the air pump will be explained, and those who desire to investigate this subject thoroughly will find Mr. Dickie's article highly interesting.

At this day it is probably hardly necessary to speak of the advantages possessed by twin-screw engines over a single screw, inasmuch as the very smallest vessels have been fitted with twin

screws, and even first-class torpedo boats are now universally so fitted. The advantages against total disablement of the machinery are obvious, and also the increased manœuvring power. In the early days of twin-screw propulsion the idea was sometimes advanced that there was a diminution of propelling efficiency as compared with single screws, but comparative trials have shown that this is unfounded, and all experience goes to show that twin screws are, at least, as efficient as single screws and probably somewhat more so.

We now have in commission one triple-screw ship and another one almost ready for her trial. This subject of multiple screws has already been discussed pretty thoroughly in print in papers published by various authors, including one by myself in "The Engineering Magazine" for February, 1894, and another by Passed Assistant Engineer Carter, on the trial of the *Columbia*, which appeared in the Journal of the American Society of Naval Engineers, for February, 1894. In the case of the *Columbia*, the reason which governed the selection of triple screws was very largely the question of the enormous power which was to be developed, about 21,000. The *New York* had already been designed with engines of 16,000 horse power, with two sets of engines on the same shaft, the idea being at low powers to throw out the two forward engines. In the *Columbia* it was believed that as good or better results would be obtained by using three screws, arranging them all so that the screws could be disconnected and revolved freely, thus using only the central screw for low powers, the two side screws alone for moderate powers up to about 17 or 18 knots, and all three for speeds in excess of that. The question of securing economy both at low and high speeds will be discussed in another lecture, but, as already stated, it was one of the considerations which was involved in the design of the *Columbia's* screws. It may be stated here, however, that it was not anticipated when the design was made that there would be any greater efficiency of propulsion than if twin screws had been used. When the *Columbia* had been tried, however, and the horse power had been accurately determined there was great surprise at the comparatively low

power for the high speed. Both had been determined with accuracy beyond doubt, but the calculations were most carefully revised, and every effort made to determine whether there was any error. It was then natural to institute a comparison between the performance of the *Columbia* and that of the *New York*. This can be readily done by what is known as Froude's method of comparison, which will be touched upon later, and it was then found that there was a decided economy of propulsion in the *Columbia* as compared with the *New York*. As the hulls were both carefully designed for high speed, and the machinery in both cases was of excellent design and built by the same firm, the only conclusion is that in this case, at least, triple screws have proved more efficient than twins. It would, of course, be unwise to generalize from this one instance, but the extended experience of the *New York* and the *Columbia* in actual cruising, and the trials of the *Brooklyn* and the *Minneapolis*, which will take place within the next year, will give us additional data on which to base an accurate opinion. It may be noted that the use of triple screws instead of twin screws, with two engines on the same shaft, reduces the number of parts of the machinery which require constant care and attention, and so should be conducive to economy of maintenance.

LECTURE II.—BOILERS.

Professor Hollis, in his lectures two years ago, very aptly compared the boilers of a vessel to the human stomach, and quoted an observation made to him by an older officer, that the thing which would contribute to the success of an officer is stomach rather than brains, the man with a good stomach outliving the man of brains, but whose digestive organs were not in good shape. The truth of this comparison must be evident to anyone who considers the matter even superficially; for in the modern man-of-war steam is the absolute life-blood of the ship, and if anything occurs to impair the efficiency of the steam-generating plant the vessel becomes simply helpless.

It seems at the present time as though we were on the eve of a revolution in boilers as great as the change from simple to compound engines twenty-five years ago. The demand for reduced weight and higher pressures has compelled the resort to crowding the type of boiler which has been in use for the last fifteen years so hard that it seems as though the limit had almost been reached, and that further progress must come about by the adoption of an entirely different form of steam-generating apparatus. At the Engineering Congress at Chicago last summer, one of the most interesting papers, and one which brought out one of the most valuable discussions, was on coil or tubulous boilers. About the same time, before the Institution of Naval Architects in England, this subject was discussed pretty thoroughly by Mr. Milton, chief engineer surveyor to Lloyd's, while at the spring meeting this year there were no fewer than three papers on this same subject, thus showing the immense interest which is taken in this question of an improved form of boiler. However, there are good reasons to believe that the present type of boiler will not be entirely displaced for some time to come, and, as we shall certainly continue to use it for some years, it will be well to devote considerable attention to its construction.

The cylindrical boiler, as it exists in naval vessels to-day, has been brought to a high state of perfection, and, if it were not for questions of weight, it is probable that there would be no serious effort to displace it. The earliest forms consist of a cylindrical envelope to contain the steam and water, with one or two furnaces with their combustion chambers and tubes leading to the uptake for establishing communication between the hot gases from the coal on the one side and the water on the other for the generation of steam. With the demand for greater powers the multiplication of units, which would have resulted from simply increasing the number of small boilers, led gradually to the increase of size and increase of number of furnaces, until at the present time the boilers of the steamers *Campania* and *Lucania* are 18 feet in diameter and 17 feet long, each having 8 furnaces, 4 at each end. Some of the plates in these boilers are 20 feet long by 7 feet broad and $1\frac{7}{32}$ inches thick. No naval boilers

have yet been built quite so large in diameter as these, although we have designed boilers 16 feet in diameter, and all our later boilers have been double ended with four furnaces at each end. In a certain sense these modern boilers are somewhat like the old-fashioned return tubular box boilers, with as many furnaces as the question of convenience of handling the finished boiler would permit of fitting. From thermal considerations alone it would seem better that each furnace, combustion chamber and tubes should be independent, so that one of these eight furnace boilers would really be equivalent to eight sets of heating apparatus in one shell. This, however, would be expensive and complicated in the making and bracing of the combustion chambers, so that the common practice now with these large double ended boilers is to have four combustion chambers, the two furnaces at each end on the same side of a vertical diameter having a combustion chamber in common. All sorts of combinations of the combustion chambers have been used, and some of the earlier double-ended boilers used under natural draft had only one large combustion chamber for all the furnaces. This, however, was objectionable because, when it became necessary to clean a single fire, the cooling effect of the cold air rushing in affected all the fires, while at present it only affects one-fourth of the boilers. Then, too, when forced draft is used, if a combustion chamber is common to all the furnaces, it would require a communication between the fire rooms at the two ends of the boiler, so that the air pressure should always be the same, while, when separate combustion chambers are used, this is not necessary.

The use of steel of high quality, and the most efficient forms of riveted joints have enabled the shells of these boilers to be made as thin as possible under existing conditions, so that there is no chance for reduction of weight in this respect. The weight of contained water also is another serious item of weight. An idea of the great weight of contained water in a large cylindrical boiler will be obtained by taking the case of the *New York*, where one of the main boilers without water weighs 82 tons, while the contained water weighs 42.5 tons. Of course, this is not entirely a disadvantage, because this large reservoir of heated

water tends to maintain the steam pressure constant, and also allows for any short stoppage of the feed pumps. At the same time it makes a tremendous amount of weight to be carried around, and it is one of the reasons for advocating the use of coil boilers.

In coil or tubulous boilers the design is radically different from the cylindrical boilers which we have just been considering. In the latter the water surrounds all the heating surface, while in the former the water is contained inside of the heating surface, which consists almost entirely of a large number of tubes of small diameter. The consequence of this radical difference is that the weight of the boiler itself, as well as of the contained water, is greatly reduced from that of the cylindrical type. As the tubes are of such small diameter they can be made quite thin and still stand very high pressures, and as their total cubical contents is small the weight of contained water is necessarily very small. In the case of the *Monterey* where cylindrical and coil boilers both are fitted, the two cylindrical boilers have together a total heating surface of 2,905 square feet with 88 square feet of grate surface, while one of the Ward coil boilers has 2,970 square feet of heating surface and about 74 square feet of grate. The two cylindrical boilers together weigh without water 48 tons, and the water in them weighs 25.6 tons, while the one Ward boiler of equivalent heating surface weighs, without water, 15 tons, and the water contained in it weighs 2.35 tons. The difference in weight is thus seen to be most remarkable.

Coil boilers present a number of advantages for use on naval vessels. These may be summarized as follows:

1. Great reduction of weight.
2. Almost absolute immunity against disastrous explosion.
3. Rapidity of raising steam.
4. Ability to stand very severe usage as regards forcing without injury.
5. Reduced first cost.
6. Facility for replacement and repair.

Against these advantages there are practically three disadvantages to be mentioned.

1. More serious effects of corrosion.

2. Somewhat greater difficulty in feeding.

3. The inability to plug a leaky tube without withdrawing the boiler from service.

With regard to the first of the advantages, the figures already given demonstrate this conclusively.

With regard to the second point, safety against disastrous explosion, it may be said that it is now generally agreed that the disaster in boiler explosions is not due to the steam contained, but to the large amount of highly heated water which, when the rupture occurs, is suddenly liberated into steam, and the kinetic energy generated is so great as to hurl the portions of the boiler in all directions, thereby causing serious disaster. In the coil boiler the amount of water contained is so very small that even if it were all liberated at once it would not be likely to do much damage beyond scalding or suffocating the people in the immediate vicinity, and it is also to be remembered that as the tubes are of a very small diameter and very strong, a rupture in one of them would probably be only a small and localized opening through which the steam would escape very much as through a safety valve. There have been instances of explosions or serious leaks with coil boilers which have caused the death of the people near by, but in almost every case these were due to some serious defect in the design of the other portions of the boiler than the tubes, or to gross neglect. The most recent case which has come under my notice was of the rupture of a malleable iron "header" in one of these boilers, but I was told by a gentleman who had investigated the subject carefully, that this header was at the bottom of the boiler where it had been allowed to become imbedded in wet ashes, and that it had corroded until it was so thin that it could not be expected to stand the pressure. The boiler was in a small yacht where the fire room was very small and was closed at the time. The rupture of the header simply let out enough steam to scald and suffocate the man who was in the fire room.

That coil boilers are quick steamers is evident when we consider that the amount of water contained in the boiler is so very

small. In the cylindrical boiler, which contains such an enormous amount of water, a considerable time is required merely to heat all this water up to the boiling point, even if there is no consideration of the safety of the boiler itself; but with its large rigid metallic structure much greater time must be allowed in order that the parts may adjust themselves gradually to the increased temperature. Coil boilers, as a rule, are so arranged as to be very elastic, so that their structure does not require any consideration at all in applying heat, and practically the only time required to raise steam is that necessary to heat up the small amount of contained water.

As a consequence of what has already been stated the boiler is perfectly safe against any amount of forcing because it is so very elastic that it adjusts itself readily to the stresses brought on by very high temperatures. This has been demonstrated again and again by all sorts of trials, and in the case of a Towne boiler, a most searching test was made by running the boiler under strong forced draft, then suddenly hauling the fire and turning a stream of water from a hose on the boiler. Notwithstanding this severe test not a single leak was developed.

The cost of these boilers is lower because they consist of a larger number of identical pieces which can be fitted up by special machinery, and as their weight is small the cost of material is naturally much less than in the heavy cylindrical boilers.

With regard to facility for renewal and repair, it is to be remarked that this is a very real advantage possessed by the coil boilers. In our modern ships with protective decks the boilers have to be put in before the protective deck is completed, and when they become so far deteriorated that it is necessary to remove them, a portion at least of the protective deck will have to be taken up in order to get them out. The coil boilers being composed of a number of comparatively small pieces, can be passed through the fire-room hatch and erected in place on board; as the portions are all small, and the work of assembling them comparatively simple, repairs are naturally easy.

Coming now to the disadvantages. Corrosion is a very serious thing with these boilers, and it is probably the main reason

why they have not long ago been adopted for a portion, at least, of the boiler power of all vessels. Our experience with the tubes of ordinary boilers has shown that with tubes of ordinary thickness, about such as are ordinarily fitted in coil boilers, the corrosion becomes very serious in about three years, after which time it is practically necessary to re-tube the boiler. Now, in an ordinary cylindrical boiler, if a tube leaks while under steam, a temporary repair can be made by plugging the tube without hauling fires or laying up the boiler, and it can be continued in use; but inasmuch as the coil boilers have the steam inside the tubes it is impossible to plug them without hauling the fires, blowing off steam, and letting the boilers cool sufficiently to get into them, or at least insert tools into them for doing the plugging. This, of course, would be a very serious matter if the boilers were of large size and only a few of them in use, as it might in some cases amount to throwing out half the power, or, in others, of stopping the machinery altogether.

The difficulty of feeding these boilers comes from the fact that the amount of contained water is so small that the cessation of the feed pump for even a very short time would allow the amount of water to be reduced below what would be consistent with the protection of the metal from overheating. However, with duplicate feed pumps, and with reasonable care and some experience on the part of the attendants, there should be no trouble on this score. One of the engineer officers on the *Monterey* wrote not long since with regard to this point as follows:

"There is no trouble about carrying the water if the stop valve is set right and water handled half way decently. One feed pump can be made to supply both the Ward and the Scotch boilers working in battery, but every chump who calls himself a water tender can't do it."

With regard to the question of corrosion, however, it should be said that there are instances on record of coil boilers which have been in use for ten years, and even longer, without giving any trouble from this cause, but they were used in fresh water and with fresh water entirely. The launch boilers of our service for the last five years have been entirely of the tubulous

type, and have given great satisfaction. In the *Monterey* an experiment is being made on an extended scale to determine the suitability of coil boilers for naval vessels. There never was any doubt about their efficient working as steam generators, the only question being whether, under the conditions obtaining on large vessels, their longevity would be such as to warrant their introduction generally. Thus far they have given every satisfaction, and in one of the most recent designs of the Bureau of Steam Engineering a division of the boiler power has been adopted, there being two cylindrical boilers and four coil boilers. Some of the details of this ship will be given in another lecture in connection with the consideration of methods of securing economy at high and at low powers.

For the reason already stated, that a leak in a single tube necessitates the laying off of a coil boiler while steam can be blown off and the tube plugged, it is evident that it would never be desirable to reduce the number of coil boilers on a vessel to a few units. Of course, this multiplication of units has the disadvantage of requiring an increased number of fittings and greater attention to the feed, but if they are to be used this disadvantage must be accepted.

In the last lecture forced draft was referred to as the means hitherto chiefly employed for reducing the weight of boilers, and we shall now consider that subject to some extent. Although only applied for about ten years in our recent ships, forced draft had been used in our Navy to a considerable extent at an earlier period. During the late war nineteen gunboats of the *Chippewa* class were designed to be used with closed ash-pit forced draft, and before that date it had been used for years on the steamers plying in the Hudson river. In a very able paper read before the Engineering Congress last summer, Mr. Howden, who has investigated the history of this subject with great care, stated that all the various methods of forced draft had been invented and tested by the late Mr. Edwin A. Stevens, of New Jersey, who began experiments as early as 1827.

The most common method of forced draft on naval vessels is the system known as closed fire rooms, where either the entire

fire room or considerable space around the end of the boilers is made air tight, and air is forced in under a very moderate pressure, ordinarily not much exceeding an ounce to the square inch, or, as it is more commonly expressed, from one to two inches of water. This is a very simple method, and when applied moderately gives general satisfaction. The other familiar method is by inclosing the furnaces and ash pits and forcing air to them through conduits. The advantage in this method is that it is capable of more exact regulation than the closed fire room; that there is not the formation of clouds of dust as in the latter, and that it is also capable of the adaptation of means of heating the air, thereby increasing the economy. Mr. Howden, already referred to, has become famous for his work in this method of forced draft, which is now applied to nearly all the principal merchant vessels of great power which use forced draft by blowers. A number of the earlier of our recent ships were fitted with closed ashpit forced draft, and the Bureau of Steam Engineering prefers that method; but in large ships, with protective decks and numerous water-tight subdivisions, it is very difficult to so locate the blowers with this method of forced draft that the fire rooms will be thoroughly ventilated. It must be remembered that when closed ashpits are used the air which goes to the furnaces and ashpits does not go through the fire room direct, but through conduits. To secure the ventilation of the fire room the blowers are ordinarily so located that the air is drawn through a hatch, and through the fire room to the blower, and then discharged into the conduit to the furnace. If this ventilation be neglected the heat will become intolerable, and the firemen will be unable to work.

Besides these two methods, another has lately been developed to a considerable extent, known as induced draft, which amounts to drawing all the air for combustion through the furnaces by means of large fans located in a chamber connected with the base of the chimney. At first sight it would seem that it would be very difficult to do this, but the firm of John Brown & Co., in England, who are supplying the Ellis-Eaves system of forced

draft, have worked out the details carefully, so that a considerable degree of success has been attained.

The earliest method of forced draft, and the one still in eminently successful use on locomotives, is by steam jets in the chimney. This, however, is entirely inadmissible on board ship in these days, when the boilers must be supplied entirely with fresh water, and the waste of steam necessary to produce the draft could not be permitted.

Still another method of forced draft, and probably the oldest of all, is by the use of a high chimney. Roughly speaking, it is sometimes stated that each additional ten feet of height in a chimney has the same effect as an additional one-eighth inch of water air pressure. The first example in recent times of the application of this principle to large vessels was a steamer built by Messrs. Denny and Bros., of Glasgow, Scotland, called the *Scot*, which had pipes 120 feet high. The success of this vessel encouraged the Engineer-in-Chief of the Navy to recommend similar action for our vessels, in which he was seconded by the Bureau of Construction and Repair, and the *Brooklyn* and *Iowa* are to have smoke pipes 100 feet high.

When this proposition was made by the Engineer-in-Chief, a gentleman near the Secretary of the Navy, but not a naval officer, conceived the idea that these tall smoke pipes would spoil the artistic effect of the vessels, and urged this upon the Secretary with such persistence that the latter required the Engineer-in-Chief to submit a memorandum showing the advantages expected before he would grant permission for the tall pipes to be used. This memorandum sets out the advantages so clearly that I cannot do better than simply reproduce them here. Before so doing, however, I would say that there is another decided advantage in these tall pipes which will be thoroughly appreciated by all officers who go to sea, and which receives added weight from a recent report from the *New York*, where the pipes were lengthened beyond the height originally assigned, some 60 feet above the grates, to about 75 feet. Chief Engineer Lowe remarks that owing to the pipes not being high enough, cinders and smoke are blown all over the ship, and whenever steaming

at any speed or with a head wind, they are blown into the cabin, making it almost uninhabitable, and down the engine-room hatches, endangering the machinery. With 100-foot pipes the smoke would all be blown entirely clear of the ship. The memorandum submitted by Engineer-in-Chief Melville is as follows:

NAVY DEPARTMENT, BUREAU OF STEAM ENGINEERING,

Washington, October 14, 1892.

Memorandum for the Honorable the Secretary of the Navy. Advantages of the 100-foot Smoke Pipes of Armored Cruiser No. 3.

1. It enables a higher average speed to be steadily maintained without any special fittings.

A fair average value of the coal burned per square foot of grate surface per hour with an ordinary 60-foot pipe is fifteen pounds.

It has been estimated, as the result of experience and experiment, that each 10 feet of additional height increases the draft as much as $\frac{1}{8}$ inch of water air pressure. Thus the extra 40 feet mean, in round numbers, $\frac{1}{2}$ inch of water air pressure.

A very conservative estimate of the increased combustion due to $\frac{1}{2}$ inch air pressure is 10 pounds per square foot. This makes the combustion with natural draft in the 100-foot pipe 25 pounds per square foot.

The effect of this in *Armored Cruiser No. 3*, with 1,016 square feet of grate surface, is to give us in round numbers 11,500 indicated horse power, instead of 7,000 indicated horse power with the shorter pipe. At the cruising displacement of 9,100 tons, this means raising the sustained speed from 15.23 to 17.20 knots, nearly two knots per hour.

2. All experience goes to show that the long continued use of forced draft by pressure in the fire room has a deleterious effect on the boilers. Even as low a pressure as $\frac{1}{2}$ inch will, after a day or two, begin to develop leaky tubes.

This is avoided when the same combustion is produced by chimney draft.

3. Hence there is an increased longevity of the boilers when the increased power is secured by a high pipe rather than by forced draft, and a saving in the cost of repairs.

4. There is an actual saving at powers below the natural draft full power of all the boilers, due to the following cause:

Whenever a boiler is under steam a certain amount of coal is expended simply in supplying the heat lost by radiation.

Experience with the smaller boilers of other ships leads to the belief that this amount for the large boilers for *Armored Cruiser No. 3* would be from 2½ to 3½ tons per day.

This means that where it would take (say) three boilers to give the desired speed with the short pipe two would do with the high pipe, making a saving due to laying off this boiler of at least 3 tons a day.

5. The high pipe will also produce an actual economy of combustion due to the more energetic combination of the oxygen of the air with the fuel. This has been shown by repeated experiments with moderate forced draft, to which, as has been seen, the action of the high pipe is equivalent in its good features.

6. There is also the saving of the extra coal needed to run the blowers. Reliable data of the power of blowers at various speeds are scarce, but available data suggest that the power of the eight large blowers of *Armored Cruiser No. 3*, to give ½ inch air pressure would be between 50 and 75 indicated horse power.

The simple engines driving these blowers are wasteful, and an allowance of five pounds of coal per indicated horse power is conservative. This means at the lowest figure taken (50 indicated horse power) 250 pounds of coal extra per hour, or nearly three tons a day.

7. The necessary location of the blowers is such that it is impossible wholly to protect the working parts from dust, so that, after steady running for some time, there is so much wear as to necessitate adjustment, or else to involve the risk of a break down. Such use, therefore, may prevent the machinery working at full power just when most needed.

It is thus seen that, besides the cost of steadily running the blowers, in coal, there is the added cost of repairs.

8. The high smoke pipe gives us the benefit of an increased combustion due to ½ inch of water air pressure without requiring a single additional man to look after it, while the use of the blowers will involve all the time of one man in any case, and when all are working, several men.

This, moreover, comes at a time when extra work comes on the coal heavers and firemen, so that, with the ordinary peace complements, all the men are needed without allowing for some to look after the blowers. The subdivision of the coal bunkers makes the work of getting out coal arduous and slow at best, and, unless there is an adequate number, there is no use in trying to increase the rate of combustion, as the coal cannot be provided as fast as it can be burned.

9. There is the further advantage that, having already raised the steady cruising speed from 15.35 to 17.2 knots, if a small additional increase is wanted, say 1 knot, this can be obtained with a moderate increased air pressure from the blowers. With the short pipe ½ inch pressure would be required, besides the amount needed with the high pipe.

It is thus seen that the high pipe—

Increases the speed without injury to anything.

Increases the life of the boiler.

Increases the economy of combustion at moderate powers.

Saves coal lost by radiation from extra boilers used with short pipes.

Saves in repairs to boilers.

Saves in repairs to blowers.

Saves extra coal needed to run blowers.

It should, perhaps, have been distinctly stated at the start that this height of 100 feet is above the lowest grates of the boiler furnaces.

The clear height above boats and other large objects on the upper deck, which is the height that appeals to the eye, is only about 45 feet.

Respectfully submitted,

GEO. W. MELVILLE,

Engineer-in-Chief, U. S. Navy.

As has been noted in the memorandum of the Engineer-in-Chief, one of the serious drawbacks attendant upon the use of forced draft is the occurrence of leaky tubes. These leaks always occur where the tubes are fastened in the tube sheet of the combustion chamber. The explanations which have been offered for this phenomenon are very numerous, and some are undoubtedly true, while others are merely fanciful. The English Navy has been particularly unfortunate in this respect, while our ships, as a rule, have fared very well, and while we have had leaky tubes now and then, we have never been compelled to abandon a trial on that account, nor in any case has a very large number of leaky tubes been found. A comparison of the boilers in our service and in the English Navy suggests that one reason for their trouble and our freedom from it may be that their boilers are much smaller for the same work. Engineer-in-Chief Melville has a favorite expression, that he never puts a boy to do a man's work, and he has faithfully carried this out in the boilers. It will be found, on investigating the subject, that in some of the English ships, where there was most trouble with the boilers, there was an allowance of not over $1\frac{1}{2}$ square feet of heating surface to a horse power, while in our service we almost invariably allow more than 2 square feet, and only in one case, so far as I am aware, has the proportion fallen below 2 feet, and then only a trifle.

It will appear obvious, on consideration, that the tube sheet and tube ends must be clean, and that there must be a fair circulation of the water around them, and this has been demonstrated conclusively to be the case by careful experiments. It had also been maintained by some able engineers that one cause of the trouble was having the tube sheets too thick. It was, perhaps, natural that, in a plate whose section was so very much reduced as is that of a tube sheet, there should be a desire to make this up by increasing the thickness. Experiments were made by Dr. Kirk, Mr. Yarrow and others which showed conclusively that when the thickness of a tube sheet exceeded certain very reasonable dimensions, say $\frac{5}{8}$ inch, there was a considerable difference in the temperature on the two sides of the tube sheet,

while, when the thickness assumed unusual dimensions, the difference in temperature of the two sides was very great.

To overcome the defect of leaky tubes without putting in new boilers the English Navy has resorted to what is known as the Admiralty ferrule, which is simply a tube with the outer end flanged over so as to protect the end of the tube from the direct impact of the flame. These have thus far given pretty general satisfaction, except that what is called "bird's nesting" seems to be more prevalent when the ferrules are fitted than when they are not. This phenomenon consists in the formation of a growth of tenacious soot or fine ashes growing out from the sides of the tubes, until it finally closes over them entirely. We have never had any trouble with this phenomenon in this country, but in England it has several times caused the loss of a trial trip.

I shall now say a few words about the care of boilers, dealing specially with those items which would be of interest to commanding officers, because I believe that if they thoroughly understood the reason why certain lines of action are recommended we should not find, as we do occasionally, that the regulations are not observed, and that a course of action is pursued which is sure to shorten the life of the boilers materially.

The subject of corrosion has already been referred to in a general way, but it should now be mentioned that at the present time this is the most serious cause of trouble in marine boilers. Modern practice insists upon the use of fresh water in the boilers so that trouble from scale has become practically unimportant. But partly for the very reason that scale is no longer present corrosion plays a more important part than ever.

In the early days of marine engineering when jet condensers were used and salt water in the boilers, every portion of the boiler below the water line was covered with scale, frequently to a great thickness, and while this was very objectionable on the heating surfaces it did no harm on the shell, and it protected all of them from the effects of corrosion. With the advent of the surface condenser and the use of water which was practically fresh, the scale was no longer formed and corrosion began to attract attention. At this date when we are in possession of

more information, it seems as though many of the explanations assigned for corrosion were exceedingly far-fetched. One theory was that the brass or copper tubes in the surface condenser formed with the iron of the boiler a galvanic battery in which the iron was the positive metal and the one to be used up. Finally, however, common sense and experiment gave us the true explanation of corrosion, which is very simple.

Corrosion, as it occurs in marine boilers, is simply rusting. In order that rust may occur four things are necessary: Metallic iron (including steel of course), carbonic acid, moisture, and oxygen or atmospheric air. Iron is unaffected by dry air at ordinary temperatures or in perfectly pure water free from air, oxygen or carbonic acid; but, if exposed to a moist atmosphere, then oxidation, commonly known as rusting, proceeds, especially if carbonic acid be also present, as is usual in the atmosphere. The presence of carbonic acid appears essential to oxidation of the iron by moisture, since the metal may be kept bright for almost any length of time in pure lime water or in a solution of soda. Under the joint influence of moisture, oxygen and carbonic acid ferrous carbonate is first produced on the surface of the iron, and this, by absorbing a further proportion of water and oxygen, becomes changed to a hydrated ferric oxide with the liberation of carbonic acid, which latter then reacts upon a fresh portion of the iron in the presence of water and oxygen, and a further quantity of ferrous carbonate is produced, and so the cycle continues to be repeated. Further, the hydrated oxide, or rust, is electro negative with respect to the metallic iron upon which it is formed, and the electrical condition thus resulting still further promotes the affinity of the metal for oxygen, and the corrosion of the iron thus proceeds rapidly.

All the conditions for the occurrence of corrosion thus exist in marine boilers, and unless care is taken corrosion will certainly occur. The air which goes into the boiler with the feed water not only contains the oxygen but also the carbonic acid, which, as has been seen, is the real active agent in the formation of rust, and it is for this reason that vapor pipes and air extractors are fitted to get rid of the air as far as possible.

It is not so much, however, while the boilers are in use that corrosion is to be guarded against, as when they are laid up, and for some time past the proper course in such cases has been very definitely known. Two methods are employed. If it is possible to keep all moisture out of the boiler and it is to be laid up for any length of time, all the water is carefully drained out, and trays with unslaked lime are shoved in through the manholes together with other trays containing burning coal, from which the gaseous portion has been driven off. The lime absorbs any moisture that may be present, and the burning coal will absorb all the oxygen, so that while carbonic acid will be left caused by the combustion of the coal, there will be neither oxygen nor moisture, so that no rusting can occur. This method, however, as a rule, is inapplicable on board ship, because it is almost impossible to wholly prevent moisture from getting into the boilers, and consequently when the boilers are not in use and are to be laid up for several weeks, they should be filled entirely full of water, a pipe being attached to the highest portion so that a slight head may be maintained and assurance felt that the boiler is absolutely full. The water should be rendered slightly alkaline by the addition of some strong alkali, and then no corrosion can occur.

The practice which sometimes prevails of attempting to trim ship by running water up and down in the boilers is reprehensible in the highest degree. It is deliberately shortening the life of valuable Government property for the sole purpose of increasing the neat appearance of the ship, and is just as unreasonable as if coal were hoisted up and dumped overboard to accomplish the same end. In fact, it is not going too far to say that it is even worse than the deliberate waste of money would be by throwing away the coal, because the latter would be a mere waste of money, while the injury to the boilers will not only eventually cost a great deal of money for their replacement, but will render them inefficient at a time when most needed. The reason why this practice of trimming ship by changing the water level in the boilers has come about is probably simply because it is so easy to do it; but this position should not lead com-

manding officers to do what is such an absolute injury to the durability and life of the machinery.

As has already been remarked, scale, which was once the great evil in boilers, now holds a very secondary place, because with the modern high pressures and high temperatures carried it has been found absolutely essential to use fresh water in the boilers and keep the heating surfaces thoroughly clean. It may not be amiss, however, to say a few words as to the rationale of scale formation. Of the saline constituents of ordinary sea water sulphate of lime forms a very small fraction, and yet of the scale deposited in marine boilers it forms almost the entire amount. The reason for this was not understood at first, and as it was assumed that sulphate of lime followed the same law as most other salts, of being more soluble in hot water than in cold, it was thought that the way to get rid of it was to allow the saline solution to become moderately concentrated, then blow out a portion of this solution and replace it with clean sea water, thereby reducing the average density. It ought to have been apparent at once, although it was a long time before it was noticed, that, notwithstanding this method of treatment, scale formed in enormous quantities. Finally a French chemist, Cousté, determined experimentally that, contrary to the behavior of most salts, sulphate of lime is less soluble in hot water than in cold, and that while the amount which is held in solution in water at ordinary temperature is small, when the temperature rises to about 295° Fah., the water will no longer hold any in solution. This temperature corresponds to a pressure of about 50 pounds, so that it is apparent that in boilers using pressures as high as this or higher, all of the sulphate of lime in the water would be deposited by mere elevation of temperature before a bit of the water was evaporated; consequently, blowing out to prevent the formation of scale was ridiculous, as it had exactly the opposite effect. At least ten years ago the Bureau of Steam Engineering issued instructions that the density of the water was to be maintained at not less than $\frac{4}{32}$ before any blowing out should occur, and thereby the formation of scale was very materially reduced with the accompanying saving of fuel. It is probable that it would be perfectly

safe to run with an even higher concentration of water than this, for a saturated solution of common salt, which is the chief ingredient in sea water, does not occur until the salt forms $\frac{1}{3\frac{1}{2}}$ of the whole solution.

At the present time the question of scale is really of importance only in connection with the evaporators used to supply the steam for the distillers and for making up losses of feed water, and the simplest method to deal with the question here is to make the coils readily removable and thoroughly accessible, so that they can be scaled mechanically with very little difficulty.

Another matter of great importance in connection with the longevity of boilers is the care used in raising steam and allowing it to fall again. Attention has been called to the advantage possessed by tubulous boilers in allowing steam to be raised very rapidly, and the very fact that this is quoted as an advantage for these boilers shows that ordinary boilers will not permit of the rapid raising of steam without injury. No matter how good the circulation in a large cylindrical boiler, there is a considerable mass of metal whose temperature is to be raised from perhaps 70 or 80 degrees to 370 or 380, while other portions which are in direct contact with the hot gases probably have their temperature considerably higher than this. Unless this change of temperature is brought about gradually, leaks are sure to be caused in the various seams of the boilers; consequently ample time should always be allowed for raising steam, and, whenever practicable, the commanding officer should notify the chief engineer at least twelve hours before steam is wanted, in order that he may make his preparations and give ample time. It does not require as much as twelve hours, but careful officers would allow in these large cylindrical boilers at least six hours for raising steam.

Appliances are now fitted for improving the circulation of the water and bringing all parts to the same temperature more readily, the most familiar of which is probably the hydrokineter, which is simply a form of injector, taking steam from another boiler and drawing in a current of water from immediately around it. It is located in a portion of the boiler where there would

naturally be very little circulation and in this way greatly increases it. The use of the hydrokineters enables steam to be raised with safety in very much less time than would otherwise be the case, as it is possible in this way actually to have the water in the boiler at the temperature for raising steam before fires are lighted at all, and with every part of the boiler warmed up to the proper temperature. Of course, this means the expenditure of fuel in furnishing steam to drive the hydrokineter, and would only be adopted when it is desired to have the boilers ready for steaming at a moment's notice, and not when a ship is in port and not expected to move for several days or weeks. Other means also exist for increasing the circulation, but they all involve the expenditure of a certain amount of steam. The particular method to be used is, of course, a matter of detail, depending on the way the ship is fitted out, but the great point in this connection is that the commanding officer should give the chief engineer ample time.

The same thing holds true with regard to discontinuing the use of boilers. Of course, it is not always possible to give accurate information as to the time when steam will no longer be required, but, if practicable, notice should be given the chief engineer at least an hour before the time when the engines will no longer be needed, so that the fires in the boilers can be allowed to burn down, and the necessity of hauling any part of them be obviated. At this day, and with modern boilers, it is an engineering solecism to haul fires except in case of an accident. When the boilers are no longer needed the fires should be so light that they will not form steam any longer, and the furnace and ashpit doors should then be closed, the fires allowed to burn completely out, the steam pressure to fall naturally, so that the boiler will cool off gradually and resume the cold condition without undue strain. To haul fires, or open furnace and connection doors, or to blow down the boiler, except in case of great necessity ought really to subject the officer doing such a thing to a court martial for incompetence and wilful destruction of Government property. These matters ought to be carefully considered by commanding officers, because no one can doubt

for a moment that the officer in command of a ship wants her to be ready for the greatest efficiency whenever called upon, and yet by neglect of these points, which may appear trivial to those who do not recognize their importance, the most important part of the machinery may be rendered inefficient, unreliable, and even in extreme cases unsafe.

It may not be amiss in this connection to say a few words in regard to the use of liquid or oil fuel. Probably every officer of the service is aware that extended experiments have been made in the Italian Navy to determine the best way to burn liquid fuel, and its general advantages for naval vessels. At the Engineering Congress last summer, Colonel Nabor Soliani, of the Italian Engineer Corps, read a most valuable paper on the subject of liquid fuel for marine purposes, a careful study of which would repay anyone interested. Time forbids going into the subject at great length here, but a few facts may be given.

It seems to be pretty thoroughly established that the only form of liquid fuel which is absolutely safe for use on board ship is what is known as petroleum refuse, which is a thick viscous liquid of about the consistency of tar or very thick molasses. This has to be sprayed or pulverized either by jets of air or steam for use in the furnaces. The simplest method, of course, would be the use of steam, but this is inadmissible on board ship for the same reason that steam jets in the chimney cannot be permitted, and it has been found perfectly practicable to use compressed air for spraying the oil. In the Italian Navy, however, the Cuniberti pulverizer uses steam because they do not contemplate the regular use of liquid fuel, but to hold it in reserve for the same object as forced draft. Colonel Soliani explains that they have found it highly efficient, and also to give a marked increase of power, to use the oil fuel in combination with coal. The boilers are fitted for burning coal in the ordinary manner with the liquid fuel fittings in addition. Ordinarily the fires are worked with coal alone, but when additional power is required the liquid fuel burners are started, and the effect is very much the same as that of forced draft.

Were it not for the great objection of high cost, liquid fuel

would seem perfection for naval purposes. The fires can be regulated to a nicety by merely adjusting a valve, there is no smoke and no ashes, the number of firemen needed to attend to a given number of fires would be greatly reduced and the fire rooms would be kept very much cleaner. The supply of fuel could be taken on board in very much less time, and there would be absolutely no dirt. The pulverizers have now been brought to such a state of perfection that there is no question about their working, and, in fact, the problem may be said to have been solved except that of cost.

In Russia the percentage of petroleum refuse is much greater than in the United States, where practically there is hardly any, the various processes of distilling lubricating and burning oils leaving a residuum of coke. At the present time, while there is not a great demand for the amount of refuse which exists, it is practicable for it to be used in certain places at a reduction of expense as compared with coal. This is notably the case on the Caspian Sea with the steamers that bring the oil from Baku. It is quite evident, however, that, as the supply is decidedly limited, if there should be any general demand for it, the cost would immediately go up to a figure that would be prohibitive. This has actually been found to be the case already in this country. Some years ago the Pennsylvania Railroad investigated the subject of the use of petroleum refuse very thoroughly, and demonstrated that it had a great many advantages, but when they came to consider the question of adopting it exclusively they found that their road alone would use almost the entire amount of petroleum refuse in this country. They found, therefore, that the question of cost rendered it impossible to take it up.

It would seem that liquid fuel is specially desirable for use on torpedo boats, and the Engineer-in-Chief has recommended in several of his annual reports that Congress should make an appropriation to enable him to make experiments to this end, but no appropriation has thus far been made. Unless unexpected supplies of petroleum should be discovered it hardly seems likely that it will become a fuel for general purposes on war vessels. Should the time come when supplies of petroleum refuse

can be obtained in many parts of the world it might be desirable to carry a reserve supply of this liquid fuel in the double bottoms, which could be drawn upon in case of emergency.

It must be emphasized that for safety it is necessary to confine the use of this liquid fuel to the petroleum refuse. Colonel Soliani dwells upon this point, and emphasizes the fact that crude oil or refuse where the distillation has not been thoroughly carried out is dangerous, while the true petroleum refuse from which all the light oils have been thoroughly removed is perfectly safe, its burning point being above 400 degrees centigrade, a temperature which need never be approached except where the oil is burned.

At the World's Fair last summer the boilers which furnished the steam for driving the machinery were all fed with crude oil, but the circumstances there were, of course, entirely different from those obtaining on board ship. The oil was stored in tanks underground and at a considerable distance from the boilers, and with thorough means for giving off the volatile gases, so that they could not be exploded. In the confined spaces on board ship this would be impracticable, and here the use of crude oil would certainly be attended with great danger. The very fact, too, that the petroleum-tank steamers which carry crude oil in bulk use coal in their boilers, and have a double bulkhead between the machinery space and the oil tanks filled with water, shows the danger that would result from the use of this material.

LECTURE III.—MARINE ECONOMICS.

Among other extremely valuable points brought out by Professor Hollis in the lectures which he gave two years ago before this College was the great effect of the auxiliary machinery upon the radius of action of the vessel. It is probable that it may have occurred to any thoughtful mind that they must have a considerable effect, and still it may have been assumed that the power of the auxiliaries was directly proportional to the power of the main engines, and that, consequently, while they had an

effect it was not so marked. Professor Hollis showed, however, from careful observation made on the *Charleston*, to which he had been attached for more than two years, that the power of the auxiliaries does not form a constant percentage of the power of the main engines, but that each one may be said to require a certain power to move it at all before it does any useful work, and that, consequently, when the main engines are developing very low power the proportion expended in the auxiliaries becomes very high.

It is to be noted in this same connection that an analogous statement applies to the main engines themselves, as a certain amount of power must be expended simply to turn them over and overcome certain inevitable losses before any useful work is done in turning the propeller. Professor Hollis showed, also, that the loss due to radiation from the boilers, pipes and other portions of the machinery would also have an effect.

The result of all this is that the theoretical calculations which would go to show that we might get an almost indefinite radius of action by running slow enough are entirely erroneous, because not considering all the elements of the problem.

It is to be noted, also, that for both engines and boilers there is a point of maximum efficiency, on both sides of which there is a loss. In the boilers, for example, it will require the combustion of a certain amount of coal simply to maintain the steam pressure and overcome the losses from radiation. After this is passed we have probably the maximum efficiency of generation of steam, which remains practically the same up to the combustion of thirteen or fourteen pounds of coal per square foot of grate surface in ordinary boilers. Beyond this point the economy of evaporation is gradually reduced until, when we are working with full power forced draft and burning forty or more pounds of coal per square foot of grate, the efficiency is decidedly reduced. As an example of the effect on boilers of various rates of combustion, I may give the experience with the test of one of the boilers of the *Cushing*, made by a Board of Naval Engineers under the presidency of Chief Engineer Loring. Attention is called to the fact, however, that in this boiler there is an unusually

large ratio of heating to grate surface, so that while the proportion between the evaporation per pound of coal at different rates of combustion is illustrative of the case of any boiler, the absolute figures would not hold for boilers with different ratios of heating to grate surface.

TABLE SHOWING VARIATION OF ECONOMIC EVAPORATION, WITH RATE OF COMBUSTION, BOILER OF U. S. S. *CUSHING*.

Air pressure in inches of water.....	0.00	0.50	3.00	4.00
Coal per hour per square foot of grate.....	7 58	24.12	40.23	66.32
Water per pound of coal from and at 212° Fahr.....	11.90	9.72	8.84	6.51
Water per square foot of grate per hour.....	90.20	234.40	355.60	431.80

From this it will be seen that when burning only 7.6 pounds of coal per square foot of grate the evaporation per pound of coal was nearly 12 pounds, while when the combustion had been increased to 66.3 pounds of coal per square foot of grate the evaporation per pound of coal fell to 6½ pounds, a reduction of nearly 50 per cent.

With the engines an analogous condition of affairs obtains. At a point probably somewhere near full power under natural draft, and with a cut-off in the high-pressure cylinder as early as the link motion will permit, the highest efficiency in the use of steam is obtained, or, in other words, the horse power is obtained for the fewest pounds of steam. As the power is increased and the cut-off becomes later, there is a reduction of efficiency on account of the reduced ratio of expansion, although probably the reduction is not very great. On the other hand, when the power is reduced below full power under natural draft the cut-off cannot be made any shorter in the high-pressure cylinder because the distribution of steam would be badly deranged with ordinary link and other gears not having independent cut-offs; so that it becomes necessary either to reduce the steam pressure, if the throttle remains moderately wide open, or else get the same effect by throttling, so that the initial pressure in the engine is very much reduced. The consequence is that more pounds of steam per horse power are required, due

both to the lower steam pressure and the increase of cylinder condensation.

The effect of running an engine at powers very much below that appropriate to the size is very clearly shown by the following table made up from Chief Engineer Isherwood's report of the trials of the yacht *Leila*. The trials had other objects, and there were variations in the regimen other than simply reducing the power, but the conditions are, nevertheless, very similar to those which obtain when running at reduced speeds in our new vessels. Trials I, J, K, and L, M, were under conditions differing from the first eight, but the same fact of reduced economy at low powers is clearly shown.

TABLE SHOWING EFFECT OF REDUCED POWER IN INCREASED COST PER UNIT. FROM ISHERWOOD'S REPORT ON *LEILA*. COMPOUND ENGINE, 9 INCHES AND 16 INCHES DIAMETER, BY 18 INCHES STROKE.

	Steam pressure.	Revolutions.	I.H.P.	Steam per hour per I.H.P.
A.	129.4	221.5	149.94	16.36
B.	127.2	215.9	145.16	16.02
C.	104.5	192.2	99.90	16.71
D.	91.4	181.1	85.74	17 44
E.	75.0	166.5	63 61	18.69
F.	54 7	145.4	42.98	20.93
G.	32.4	111.5	20.71	24.95
H.	21.3	94.7	12.76	32.72
I.	103.6	188.1	93.72	18.47
J.	74.5	167.3	60.31	20.13
K.	55 8	145 9	39.19	23.90
L.	61.6	197.9	107.69	21.03
M.	21.0	122.6	33.23	28.61

As very reliable data are available of the test of an economical cargo vessel, I have taken the data for an ordinary two days' run of the *Baltimore* at the same speed, and in the following table give a comparison of the two cases, showing the immensely greater economy of the merchant vessel whose engine is running at very nearly full power as compared with the war vessel whose engines are developing less than one-tenth of maximum power:

COMPARISON—*BALTIMORE* AND *IONA*.

	Baltimore.	*Iona.*
Length	315.	275.1
Beam	48.5	37.3
Draught, mean	21.25	20.67
Displacement	4,938.5	4,430.
Coefficient of fineness	0.535	0.765
Speed	8.6	8.6
I.H.P. main engine and connected auxiliaries	877.5	645.4
Coal per day " " tons	31.5	10.1
Coal per hour, pounds	2,950.	942.
Coal per I.H.P. "	3.35	1.46
H.P. cylinder, diameter, inches	(2) 42.	(1) 21.88
I.P. cylinder, " "	(2) 60.	(1) 34.02
L.P. cylinder, " "	(2) 94.	(1) 56.95
Stroke, "	42.	39.
Revolutions per minute	50.	61.1
Ratio of H. S. to G. S. in boilers	25.4	75.0
Maximum designed I.H.P.	10,000.	750.

Professor Hollis worked out a table with great care, showing the distribution of power among the main engines and the auxiliaries of the *Charleston* for speeds ranging from about 4 knots up to the maximum, and this is so interesting and valuable that it is reproduced here.

The facts disclosed by this table will probably be startling to a great many, as they show that at low powers the percentage of the coal burned which is utilized in the main engines reaches so low a figure as about 30 per cent.

The determination of the most economical speed by a simple formula is not practicable, because in addition to the complications which have already been mentioned, the other fact comes in that the horse power necessary to propel the vessel does not vary in any strictly simple ratio. It is ordinarily assumed that the ratio of the two horse powers required for two different speeds will vary as the cubes of the speeds, and at moderate speeds this is approximately true, although when the speeds become high in proportion to the size of the vessel this ratio is exceeded and sometimes is as high as the fourth power.

Professor Hollis showed in a paper subsequently written for the American Society of Naval Engineers, that if a curve be

TABLE SHOWING COAL EXPENDITURE OF U. S. S. *CHARLESTON*.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
Knots, speed.	I.H.P. main engine.	Coal per I.H.P.	I.H.P. air pump.	I.H.P. circulating pump.	I.H.P. feed pump.	I.H.P. blowers.	I.H.P. main bilge pump.	I.H.P. other auxiliaries.	I.H.P. total auxiliaries.	Coal per I.H.P. auxiliaries.	Coal per hour, auxiliaries.	Coal for radiation, leakage and losses.	Coal for distilling, &c.	Coal for main engines.	Total coal per hour.	Knots per ton of coal.	Per cent. of coal in main engines.
4	107	4.0	23.7	19.4	2.5	0.	6.9	26.5	79 0	6	474	655	100	428	1,657	5.41	25.8
5	180	3.5	23.9	20.1	2.8	0.	6.9	26.5	80.2	6	481	655	100	630	1,866	6.00	33.8
6	270	3.25	24.2	20.8	3.1	0.	6.9	26.5	81.5	6	489	655	100	878	2,122	6.33	41.4
7	380	3.0	24.6	21.7	3.6	0.	6.9	26.5	83.3	6	499	655	100	1,140	2,394	6.55	47.6
8	520	2.8	25.1	23.2	4.2	0.	6.9	26 5	85.9	6	515	655	100	1,456	2,726	6.57	53.4
9	700	2.6	25.7	24.6	5.0	0.	6.9	26.5	88.7	6	532	655	100	1,820	3,107	6.48	58.6
10	960	2.5	26.5	27.3	6.2	0.	6.9	26.5	93.4	6	560	780	100	2,400	3,840	5.83	62.5
11	1,290	2.4	27.6	30.6	7.5	0.	6.9	26.5	99.1	6	595	780	100	3,096	4.571	5.39	67.7
12	1,710	2.3	29.0	35.9	9.3	0	6.9	26.5	107.6	6	646	905	100	3.933	5,584	4.82	70.4
13	2,220	2.2	30.7	41.1	11.4	0.	6.9	26 5	116.6	6	700	1,030	100	4,884	6.714	4.34	72.7
14	2,820	2.1	32.7	47.5	14.0	2.5	6 9	26.5	130.1	6	781	1,030	100	5.922	7,833	4.00	75.6
15	3,550	2.0	35.2	58 0	17.1	6.4	6.9	26.5	150 1	6	901	1,030	100	7,100	9.131	3 68	77.8
16	4,370	1.9	37.9	70.0	20.6	17 6	6 9	26.5	179.5	6	1,077	1,030	100	8,303	10,510	3.41	79.0
17	5,220	2.1	40.7	84.8	24.0	36.8	6.9	26.5	219.7	6	1,318	1,030	100	10,962	13,410	2.84	81.8
18	6,120	2.5	43.7	114.0	28.0	69.6	6 9	26.5	288 7	6	1.732	1,030	100	15,300	18,162	2.22	84.2

constructed showing the pounds of coal required per hour to secure a given speed, the most economical speed will be given by drawing a tangent to the curve through the origin, and he showed also, as might have been expected, that any line drawn through the origin other than tangent and cutting the curve in two points will give two speeds which are equally economical.

This is a point of considerable importance, because in running a given distance the commanding officer might be able to save in the coal used by the difference between arriving at the point of destination before dark in time to come to anchor that night, or reaching it in the middle of the night when he would have to stand off and on until the next morning. After the vessel has been in commission and has made several runs it is possible to construct this curve of coal consumption for various speeds, and it would be advisable for the commanding officer, whenever he had to make a trip, to consult the chief engineer as to the speed which would get them there with the greatest economy of time and coal. And in this connection it is well to mention the fact that the best way to secure efficiency is for the commanding officer to fix the speed he desires to maintain and leave to the chief engineer the determination of securing that speed with the least expenditure of coal. The writer once knew of a vessel where the commanding officer fixed the coal consumption after a few runs under particularly favorable circumstances, and fixed it at a point so low that it was impossible to maintain the fires efficiently after steaming a few hours. Had the matter been left entirely to the judgment of the chief engineer he could have fixed the coal allowance so that it would have been suitable for the occasion, and the best economy maintained. Such was the practice on another ship, and in this case there was never any trouble, and the vessel was always steamed under the most economical conditions. It is certainly fair to assume that the chief engineer has the same interest in economy as the commanding officer, and in addition his professional pride as an engineer ought to make him even more anxious to secure good results with the greatest economy of fuel. If the commanding officer fixes the coal allowance, the chief engineer has not the same incentive as where he is asked to

secure a given result with the greatest degree of economy. I would emphasize, also, the point which has already been made of the desirability of so timing the arrival of the ship as to get into port without having to stand off and on during the night. In one ship to which the writer's attention has been called this standing off and on was an almost universal occurence, and the result was very disheartening to the engineers. One of the engineers had endeavored by repeated experiments in varying the steam pressure, point of cut-off, and all other features to get the best possible result from a given weight of coal, but when he found that, after taking great care and trouble to save a few tenths of a pound of coal per horse power, many times what had been saved in this way was thrown away by simply standing off and on during the night, he felt that it was hardly worth while to go to this trouble.

As so much has been said about reduced economy at low speeds, it may not be uninteresting to notice a very creditable performance of one of our new vessels in long distance steaming. About a year ago, the *Philadelphia* made the voyage from Callao to Honolulu at an average speed of 12 knots for the entire distance, and burning 2.33 pounds of coal per I.H.P. The speed was high enough in this case to require a fair amount of power, so that the engine efficiency is much higher than for the case of the *Baltimore* at 8.6 knots already given. The table on the opposite page contains the data for the voyage of the *Philadelphia*.

The point has already been noticed that the auxiliaries on a modern ship, when the main engines are working at low powers, require the expenditure of far more coal than the main engines themselves. These engines are truly auxiliaries, but in the modern ships they have grown in number and importance until this term auxiliaries is apt to be misleading. Many persons are surprised at the amount of coal required to operate them because the very term auxiliaries seems to indicate something of inferior importance and which might almost be neglected.

The main reason for the great expenditure of coal in these auxiliaries is the fact that nearly all of them are simple engines

VOYAGE OF U. S. S. *PHILADELPHIA* FROM CALLAO TO HONOLULU.

Date.	Position at noon.				Distance knots.	Coal for steaming, galley, distilling and all other purposes, tons.
	Latitude.		Longitude.			
	Deg.	Min.	Deg.	Min.		
August 26, 1893	Left Callao, Peru, 6.15 P.M.				.....	.....
August 27, 1893	10	13 S.	79	46 W.	188	30
August 28, 1893	8	24 S.	84	17 W.	288	38
August 29, 1893	6	39 S.	88	39 W.	280	39
August 30, 1893	4	53 S.	92	54 W.	275	37
August 31, 1893	3	05 S.	97	26 W.	292	38
September 1, 1893	1	19 S.	101	56 W.	289	38
September 2, 1893	0	16 N.	106	42 W.	301	38
September 3, 1893	2	02 N.	111	52 W.	330	38
September 4, 1893	3	52 N.	116	50 W.	320	38
September 5, 1893	5	43 N.	121	13 W.	285	38
September 6, 1893	7	57 N.	124	55 W.	258	37
September 7, 1893	9	46 N.	128	38 W.	246	38
September 8, 1893	11	39 N.	132	59 W.	282	37
September 9, 1893	13	35 N.	137	25 W.	284	38
September 10, 1893	15	31 N.	142	00 W.	291	38
September 11, 1893*	17	32 N.	146	20 W.	278	38
September 12, 1893	19	15 N.	151	33 W.	320	47
September 13, 1893	21	19 N.	156	43 W.	320	48
September 13, 1893	Arrived Honolulu 4.10 P. M.				73	10
Total					5,200	†703

*September 11 had target practice.

†The coal given in the columns was by the hourly tally. Inspection of the bunkers after arrival at Honolulu showed that the amount actually expended was 747.44 tons, so that the daily amounts in the columns should be increased by 6.3 per cent.

Difference of time between Callao and Honolulu, hours and minutes	5–22
Total distance steamed (not including steaming during target practice), knots	5,200
Total time (deducting time spent in target practice), days, hours and minutes	18–1–17
Average speed per hour, knots	12
Coal consumed per 24 hours, tons	41.51
Number of knots per ton of coal	6.9
Pounds of coal per knot	321.95
Kind of coal	Cardiff, Ocean Merthyr.
August 26th to September 8th under boilers A and B.	
September 8th to September 13th under boilers C and D.	
Number of revolutions made by starboard engine	1,752,038

Number of revolutions made by port engine	1,748.387
Average revolutions per minute (mean of both screws)	67.325
Mean I.H.P. (both engines and auxiliaries)	1,519.
Coal per I.H.P. of main engine and engine room auxiliaries (deducting 3.5 tons per diem for galley, distilling and auxiliaries outside of engine-room), pounds	2.33
Slip, per cent. (mean of both screws)	11.43
Mean draught for voyage, feet and inches	21–4 5
Mean displacement for voyage, tons	4.995.

and running under conditions of extreme wastefulness as regards efficiency of steam using. This, however, is inevitable in many cases. The feed pumps, for example, must be of such construction that they will be absolutely reliable at all times and derangement will be almost an impossibility. This has led to the use of a duplex pump, which, while one of the most efficient as regards steady work, is one of the most inefficient as regards steam consumption. Experiments made on the ferry boat *Bergen* with great care showed that these slow-moving simple engines under ordinary conditions will require as much as 120 pounds of steam per horse power, which is at least six times as much as in the main engines under fair conditions of efficiency, and eight times as much as the economical triple-expansion engines of merchant steamers. Somewhat the same thing is true of the air-pump engines when independent. Attempts have been made to drive these by compound engines, but the conditions are such as not to render this satisfactory, and it has been found that we must either resort to very slow-moving engines with tremendous steam expenditure per horse power, or else to fast running engines with accompanying losses due to increased friction. Similar statements hold true also for the engines driving the circulating pumps, the blowers and other pumps, because while the former are high-speed engines they are simple and require a large consumption of steam per horse power, and the latter are necessarily slow moving and very wasteful of steam. The electric-light engines also consume very much more steam than might be anticipated, from the fact that they are usually simple engines and work practically non condensing.

In the first lecture mention was made of a paper by Mr. Dickie

before the Engineering Congress, on auxiliaries on board ship, and that he advocated the attachment of the air pump to the main engines. As has already been mentioned, simple engines working at slow speeds use an amount of steam per horse power which is very high, so that, although the horse power of the engines themselves may not be very great, the coal expenditure required does amount to a considerable figure. If the air pump were driven from the main engines the same economy of operation would be secured as holds for them. The reason why the air pump was disconnected from the main engines was that at high speeds it became comparatively inefficient, it seeming to be a condition of efficiency of the air pump as ordinarily constructed that it shall move slowly and give plenty of time for the water and vapor to pass through the valves. Mr. Dickie believes, however, that by a slight modification in the way of driving the air pump it can be made just as efficient at high speeds as at low, and he believes that with triple-expansion engines the importance of having a vacuum in the condenser before the engine is started is not very great owing to the position of the cranks of the main engine which renders it very easy to start from any position. This facility of starting, however, only holds when the engine is being worked at high powers. At low powers, with very low receiver pressures, a good vacuum in the condenser is almost a necessity.

In this connection mention may be made of a high-speed air pump, invented by Passed Assistant Engineer F. H. Bailey, now the chief designer for the Bureau of Steam Engineering, which was described at length in the last annual report of the Engineer-in-Chief. This pump has not thus far been applied in large sizes, but the ones which have already been used in small sizes have given wonderful results. One was used on a steam launch, and, under unfavorable conditions in the condenser, a vacuum of 21 inches was secured when the air pump was making a thousand revolutions per minute. The condenser was one of the ordinary keel variety, and as the propeller had to be disconnected in order that the engine could run at this high speed the cooling water was simply that due to the current of the river in

which the launch was anchored and did not exceed three knots per hour. With a good flow of circulating water through the condenser the vacuum would undoubtedly have been much higher, as with 250 revolutions per minute a vacuum of 25 inches was maintained, which of itself is a phenomenal result.

Another method which has been repeatedly suggested for increasing the efficiency of the auxiliaries and for which provision is made in nearly all our engines is to have them take steam from the boilers and exhaust into the first receiver, or from the first receiver and exhaust into the second. When this is done it in effect renders the auxiliaries an extension of one of the cylinders of the main engine, as, for example, when taking steam from the first and exhausting into the second receiver it really amounts to an enlargement of the intermediate cylinder.

It may be well to emphasize here the fact that the auxiliaries are not only important from their being absolutely essential to the efficiency of the entire machinery, but from being so very numerous, and having in many cases just as many parts to be looked after as the main engines and in others almost as many, which require an enormous amount of attention to keep them in an efficient condition. There was at one time in the Service an idea that when the ship reached port the duties of the engineer department were practically over, and that except cleaning up the engines there was nothing to do. No mistake could be greater than this, and the writer remembers, when still a cadet at the Naval Academy, hearing a very able officer, now on the retired list, Passed Assistant Engineer Manning, state the case in this way: that when fires were hauled the engineer's most important work began. It is, perhaps, natural that officers who are not personally acquainted with the details of machinery should think, when it runs along smoothly, day after day, without giving any trouble, so far as they know, that this will be kept up indefinitely without any work, very much as a good watch when once put in order by the watchmaker will run for several years without any further attention. But the comparison is far from exact. The conditions are entirely different, and just as it has been said that the price of liberty is eternal vigilance, so it

may be said that the absolute requirement for efficiency for naval machinery is unremitting care and attention; consequently nothing could be more short sighted than the policy, which I regret to learn obtains on some ships, of taking away the men of the engineer's force from their natural work for drills and other things outside of the engineer department, simply because it is supposed that there is no work for them to do below.

Now, in the first place, it is hard to see why, if there should come an occasional time when work slacks up a little in the engineer department, the men of that department should immediately be taken away and be put on other work. The same course is not followed by any means with the men on deck. After their regular work is done if there is nothing for them to do they are given a reasonable degree of rest, and the work which comes on the men of the engineers' force is so exacting, even under the best circumstances, that if they do get a chance to rest they should be allowed to enjoy it. Then, too, it has a most discouraging effect upon them to take them for work outside of their own department, particularly as it is ordinarily work of a kind which they consider beneath them. The writer knows from personal experience that men of the engineers' force, who would hesitate at no work coming in their regular line, however exacting or disagreeable, feel humiliated when called upon deck to do the same kind of work as that performed by landsmen and other people entirely without experience. While the average fireman is not a skilled mechanic, after a certain length of service he does work which requires a great deal of skill, and he is proud of it. Now it is undoubtedly the aim of every commanding officer to secure the highest efficiency in every part of the ship, and if there is one portion which should be encouraged in every way it is the engineer division; consequently, it would seem that taking the men of the engineers' force for work outside of that department, except in case of absolute necessity, is a serious mistake.

It is gratifying to be able to believe that such practices exist on only a few ships, but on one not long since every man in the

engineers' force was, by the personal order of the commanding officer, put at work scrubbing paint work, with a written order that this cleaning should be continued until every part of the engineer department was as clean as a parlor, while at the same time the machinery, which required overhauling and adjustment, was by his express order absolutely neglected. Not long after this a serious breakage occurred in one of the cylinders. It would perhaps be too much to say that this breakage could have been avoided if the proper overhauling had been allowed, but it is possible that the effect might not have been so bad if the overhauling and inspection had taken place as it should. Reports have also recently been received from one of our finest new vessels of great discontent in the engineer department because the executive officer seemed to be disposed to "horse" the men of the engineers' force. This is a cause for great regret. Personal peculiarities of officers cannot, of course, be provided for by regulation, but an appeal should at least have some effect on every officer in inducing him to do his share towards making the service as attractive to all the men as possible, and increasing its efficiency.

In the paper of Mr. Dickie, already referred to, he called attention to the multiplicity of auxiliaries on board ship, and proposed a plan for their reduction in number and a simplification of the method of driving them, by substituting in many cases for simple engines a form of water motor, known as the Pelton wheel, which from experience on land has been shown to be comparatively light and highly efficient. He worked the matter out in considerable detail for one of our battle ships, making a comparison with the steam-driven auxiliaries, and figures out a saving of weight of 30 tons. The scheme is very promising, and the Engineer-in-Chief has the matter under advisement, and has already taken steps towards experiments to determine whether this would be as well adapted to use on board ship as has been thought.

This matter of the method of driving the auxiliaries has been considered from time to time by very able engineers, and some

two years ago Colonel Soliani, who has already been mentioned, published a paper in the "Rivista Marittima," which was translated into English and published in the "Journal of the American Society of Naval Engineers," by Passed Assistant Engineer Worthington, on the method of driving auxiliaries on board ship. Colonel Soliani considered the four cases of using steam, compressed air, hydraulic power and electricity, and the result of his careful investigation and quantitative data was that steam is decidedly the most economical in point of weight and simplicity. This point is mentioned because we frequently hear the statement made that it would be much better to drive all the auxiliaries by electric motors. It is quite possible that there are certain small machines which could be driven advantageously by electric motors, where the power required is small and the machines themselves are so located that the heat accompanying a small steam engine would be objectionable. But it must not be forgotten that when driven by steam all that is necessary is to lead a pipe from the auxiliary steam main and another short pipe to the exhaust main, while when an electric motor is employed we must have an engine, larger than the one required to drive the machine, to drive the dynamo and this in turn to drive the motor, and up to the present time even high-speed motors are heavier than steam engines to do the same work, while low-speed motors are very much heavier, and are still too fast, as a rule, to drive the machine direct, which would involve the introduction of gearing. It is also an objection to the use of electrically driven machinery in many cases that if a fault occurs in the electric mains it is frequently very difficult to locate, while a leak in the steam mains always makes itself known and is easy to repair. A report from one of our new ships states, with respect to this matter, that a number of the wires used for signalling and similar purposes were out of order, and while, after considerable trouble, the location of the defect had been approximately ascertained it could not be remedied without a change of the location of the wires and at considerable expense. The report also states that a number of important telegraph signals have never worked at

all. It can readily be seen that a means of transmitting power which is subject to these defects would hardly be applicable to use where the power must be absolutely reliable.

Another thing often forgotten is that, while for small electric-lighting plants the wires necessary to convey the current do not have to be very large, if it were desired to transmit any considerable amount of power, the wires would have to be increased in size, and provision made for getting rid of the heat generated by the passage of the current.

The paper by Colonel Soliani, already referred to, gives some very interesting data on this point of the size of the electric mains for transmitting power, and the weight and cost of electric machinery. He takes the case of one of the large Italian battle ships, where the total power of the auxiliaries is about 2,400 horses, on which the weight of steam engines, dynamos and motors would have to be based; but as he takes the probable case that only half of this machinery would be in operation at any one time, the size of the electric mains or steam pipes for conveying the power would only be based on 1,200. He speaks as follows with regard to the use of electricity:

"In the plants at present used on shipboard a very low potential is used, ordinarily 65 volts, which for electric-light service seems suitable; but it would not be practicable in the case of a general system for the transmission and distribution of energy, because of the enormous current which it would be necessary to pass through the circuit. Indeed, allowing an electric efficiency of 90 per cent. between the generating dynamo and the electric motors, the electric power at the beginning of the circuit should be 1,333 H.P., to produce which with a potential of 65 volts would require a current of 15,000 amperes. And since the circuits would be insulated, and would not transmit a current of over two amperes per square millimeter of section, it follows that, at the beginning, the two branches of the circuit should each be composed of a bundle of 75 wires with a cross-section of one square centimeter each. [These wires, if consolidated into one, would make a copper bar nearly four inches in diameter.] The

weight of the whole circuit would be about double that calculated for the steam or water circuits.

"Moreover, it would not be practicable to use such a low voltage on account of the difficulties which would be encountered in installing on board ship dynamos developing more than 1,000 amperes, and because to obtain all the power necessary with machines of 1,000 amperes would require a battery of fifteen dynamos. With so many machines in operation the probability of breakage would be great, and it would be difficult to obtain from them the regularity of action which is requisite. It would be necessary, then, to have fewer generating dynamos. This can be done by increasing proportionately their potential. Thus, with a potential of 200 volts, the number of dynamos required would be reduced to five, a number which is admissible. An extra dynamo should be provided for use in case one of those in operation broke down. For the electric-light service, which requires a lower potential, it would probably be found expedient to provide the special machines and circuits now in use. I do not take this into account, and suppose, for the sake of simplicity, that the electric-light service is supplied by the large dynamos used for the transmission of power."

Adopting this solution, the weight of the circuit would be reduced to a third of the preceding, and then it would be about two-thirds of that calculated for steam or water. The six dynamos would have to be driven by steam engines of 320 horse power each. Estimating the combined weight of the dynamos and engines on the basis of 100 kilos per horse power, which figure is rather low, this gives a total weight of 192 tons. Electric motors weigh from 50 to 100 kilos per horse power, according to the type, speed, etc. Supposing we adopt the lightest, the weight of the motors required to actuate all of the auxiliary machinery on board, which requires a total of 2,400 horse power, would amount to 120 tons.

Applying the coefficients previously established in the case of steam for the cost of this apparatus and space occupied, which are sufficiently applicable to the case in question, we have:

	Circuit.	Machines for transforming energy.	Motors for Auxiliaries.	Total.
Tons, . . .	9.6	192	120	321.6
Francs, . . .	48,000	576,000	360,000	984,000
Cubic meters,	12	160	100	272
Cubic feet, .	425	5,650	3,530	9,605

To show clearly the difference in weight and cost of the electric and steam systems, I have appended the table from Colonel Soliani's article which shows the same data for the steam system as has just been given for the electric. This is as follows:

	Circuit.	Motors for Auxiliaries.	Total.
Weight in tons, ...	12	96	108
Cost in francs, ...	60,000	288,000	348,000
Volume in cubic meters, . . .	15	80	95
Cubic feet, ...	530	2,825	3,355

From this it will be seen that, speaking roughly, the weight of the electric system would be three times that of the steam, and the cost nearly three times as great, while the space occupied would also be nearly three times as great.

While on this subject of electricity for transmission of power, mention may be made of the subject of storage batteries for driving launches. All those who attended the World's Fair at Chicago last summer must have been impressed with the wonderful adaptability of storage batteries for this purpose as there shown by the launches running on the lagoons absolutely without noise, smoke, heat or any other objectionable features, and it doubtless occurred to many naval engineers, as it certainly did to the writer, to consider the feasibility of using storage batteries

for naval launches, at least to some extent. Owing to the kindness of the vice-president of the company which controlled the electric launches, the writer was enabled to procure some very valuable data in regard to them, and the weight of their ma-machinery as well as the weight which would be required for large powers to be used for any considerable time. The service in the lagoons at Chicago was very easy. There was no reason why the launches should go fast, as people usually made the trip for purposes of sightseeing, and slow speed was desirable; consequently they would run with a single charge for many hours. When the problem is changed, however, and it becomes desirable to run a boat at high speeds for a considerable time, it will be found that storage batteries are inadmissible because their weight is simply enormous. If it were desired to fit up a launch as a pleasure boat entirely for making short trips from the ship to shore, storage batteries might be fitted, but it would have to be understood that this boat was simply a pleasure boat, and when at sea the storage batteries would have to be removed, so that in case the boat had to be used in abandoning ship it could be propelled by oars or sails. Just before going to Chicago the writer had been much interested in the designs of the Bureau of Steam Engineering for the machinery of the third-class torpedo boats which are to be used on the *Maine* and the *Texas*. The *Maine's* torpedo boats are to make 18 knots, developing 200 horse power, and the entire weight of machinery, water, stores and coal is 14,240 pounds. It became a matter of interest, therefore, to inquire of the experts connected with the Electric Launch Company what would be the weight of electric machinery required to do the same work as the steam machinery would do in these torpedo boats. The very first question asked, of course, was, how long must the power be developed, and the answer was that it would be required about four hours. The electrician of the company, after some little thought and calculation, then replied that the weight of storage batteries alone to develop 200 horse power for four hours would be over 80,000 pounds. This is over 35 long tons, and as the displacement of the *Maine's* torpedo boat

is only 14.8 tons, the utter hopelessness of using storage batteries for powering boats for other than pleasure purposes became at once apparent.

In the first lecture reference was made to the problem which should be fulfilled by naval machinery of working with economy both at high and at low powers. The practice in all our recent designs has been to build vessels to make anywhere from 18 to 23 knots at full power, while in ordinary cruising they are expected to run at speeds of from 8 to 11 or 12 knots, which means that at the reduced speeds the powers will be only one-eighth or one-tenth as great as at full power. It has already been stated in this lecture that there is a great reduction of economy of steam when engines are working much below their full power, and it can readily be seen, therefore, that when the same engine is to be worked at one-tenth its full power the economy must be very materially reduced.

The first ship in which the attempt was made to combine efficiency at both powers is the *Maine*, where provision is made for disconnecting the large low-pressure cylinders, leaving the high and intermediate to be run as a smaller compound engine, and this undoubtedly will be much more economical than the large main engine at the reduced powers.

The next case was the *New York*, where there are two triple-expansion engines on each shaft, provision being made for disconnecting the forward engine at low speeds, leaving the after engines to drive the propellers. This, of course, even if the engines could be worked up to the same number of revolutions as at full power would reduce the power by a half; but working as they readily can, with a cut-off at about half the stroke at something below natural-draft full power, they ought to be very economical for perhaps one-fifth or one-sixth of the full power. The objection to this method is the multiplication of parts.

The next attempt to solve this problem is the *Columbia*, with three separate engines, all of the same size. Here three combinations of the engines can be made securing three degrees of power, and, as the single engine can be worked with economy at less than

half its power when all three engines are working, we get down to one-seventh or one-eighth of the power of all three engines. Naturally there is a certain amount of loss due to dragging the two propellers which are disconnected, but the loss due to this is not as great as might be anticipated by some. Years ago, at Mare Island, Chief Engineer Isherwood made an elaborate series of experiments with screw propellers, which included the determination of the amount of power required to drag a propeller which was allowed to revolve freely through the water and its effect in reducing the speed. His experiments showed that the power required to turn the propeller when allowed to revolve freely was comparatively insignificant, and there can be little doubt that the increase of economy of a single engine working under economical conditions will much more than overbalance the loss due to dragging the two side propellers when allowed to revolve freely.

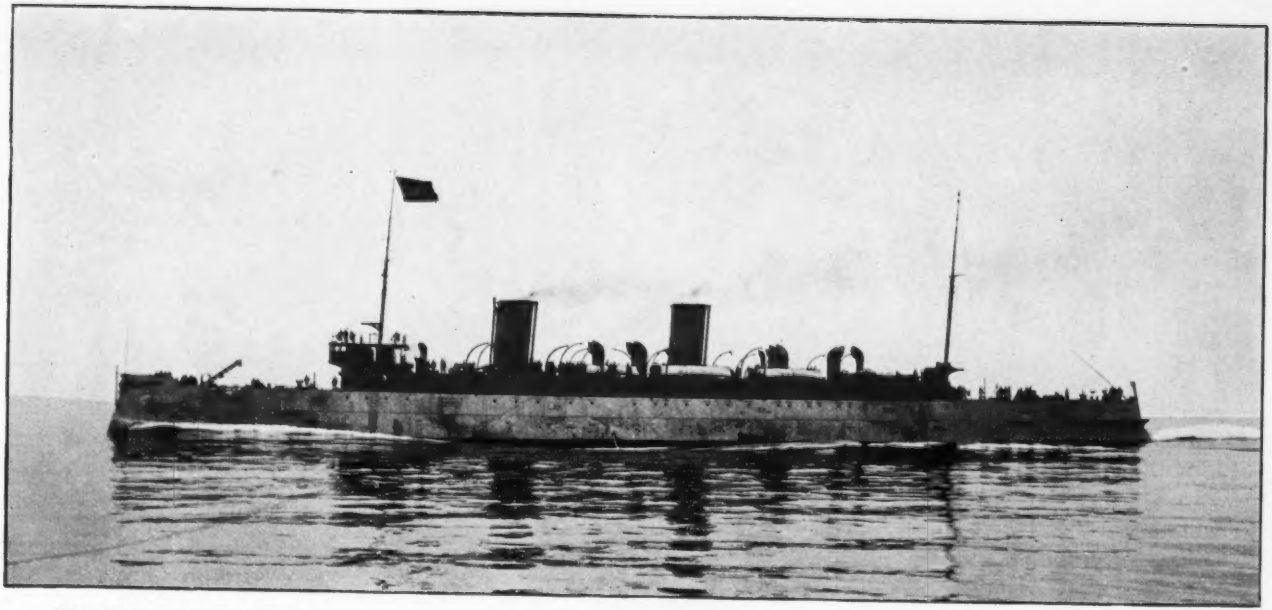
The latest solution of this problem is presented in *Gunboat No. 7*, the primary idea of which was due to Professor Hollis while still an officer of the service and one of the designers in the Bureau of Steam Engineering. In this case the engines at full power will be quadruple-expansion, the steam for the high pressure cylinders being supplied by coil boilers, while two cylindrical boilers, which are also fitted, will supply steam to the first receiver, provision being made to deliver the steam from these two boilers into the receiver at the same pressure as the exhaust from the high-pressure cylinder. At reduced powers the large low-pressure cylinders will be disconnected, and the three remaining smaller cylinders will constitute triple-expansion engines working with steam of 160 pounds pressure either from the two cylindrical boilers or from the four coil boilers as may be desired. This is one of the most novel designs which has been brought out in marine engineering for many a year, and there is every reason to anticipate great success from its use. It is a particular advantage of this plan that the boilers which will be ordinarily thrown out of use when running at low speeds are themselves very light, so that the design has enabled powerful machinery to be obtained on very light weight.

CONTRACT TRIAL OF UNITED STATES TRIPLE-SCREW PROTECTED CRUISER *MINNEAPOLIS*.

By Passed Assistant Engineer Albert B. Willits, U. S. Navy.

On July 14, 1894, the U. S. S. *Minneapolis*, the second of the triple-screw steel cruisers of the United States Navy, with a displacement of about 7,387 tons, maintained for four consecutive hours an average speed of more than 23 knots per hour on her official trial over the accurately measured deep sea course between Cape Ann, Massachusetts, and Cape Porpoise, Maine; thus fairly and gracefully transferring to her own masthead the trophy "broom," and to her name that restless phrase, *the fastest vessel of her class afloat.* In these days of progress it is doubtful if such honors can long be held by any one champion ship, but while of late the steps of advance in speed have been rapid they are ever becoming shorter, and unless some most remarkable improvement occurs in our methods of propulsion, we may not expect the next pennant winning cruiser to add more of an increase to the record of the *Minneapolis* than did the latter to that of the *Columbia*, a few tenths of a knot. However, we give all honor to the head of the class, be that head changed never so often, and as the story of the trial trip of the *Minneapolis* may, for this reason, be interesting even at so late a date, it will be briefly sketched before the more important tabulated data is presented to the readers of the Journal.

This vessel being an almost exact counterpart of the *Columbia*, in hull and engines, but having a slightly greater boiler power than the latter, was expected, from the very beginning of her construction, to have a greater speed under similar conditions



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U. S. S. "MINNEAPOLIS."

on trial, and there is no doubt but that the result filled less the hopes of the officials and contractors than it did their calculations, seeing that these hopes were born after the surprising success of the *Columbia.* The full consideration of the enormously increasing cost, in power, of every additional tenth of a knot at such speeds, came only after the test, and while it prevented some professions of a disappointment which had no rational basis, it rather moderated the enthusiasm which should have greeted this magnificent performance, in which more than two thousand horse power was added to the figures of the total indicated horse power developed by identical engines on the *Columbia.*

After the usual preparations given a naval ship before trial, and an uneventful trip from the Cramp's ship yard on the Delaware to Boston, Massachusetts, during which the machinery gave evidence of the great care that had been bestowed upon its construction and adjustment, the contractors announced that they would be ready to make the official run on Saturday, July 14, 1894.

By the terms of the contract the vessel was to make an average of twenty-one knots per hour, for four hours, failing which the contractors would have to pay a penalty at the rate of $25,000 per quarter knot decrease. Under the circumstances of a fine precedent, there was no anxiety, of course, regarding this portion of the contract, but there was much less speculation upon the possibilities embraced in a preceding sentence of the same paragraph, which set forth that a bonus would be paid for any excess of speed over twenty-one knots, at the rate of $50,000 per quarter knot.

The ship had reached her anchorage at Boston on the afternoon of the 11th of July, and had it not been for a peculiar combination of day, date and ship's number, it is probable that the trial would have been made a day earlier. But to start out on such a nerve trying ordeal with a ship designated as *Cruiser No. 13*, on a Friday, and on the 13th day of the month, was too much for the spirits of the majority of the working force below decks, and, as little things often have most potent influences on great results, this superstition was not overridden by the authorities in

charge. The time at anchor was, however, fully utilized in refining the preparations for the run, such as making slight readjustment of brasses, cleaning oil piping, cleaning furnaces, filling boilers with clean fresh water, operating the pumps, and last, but not least, giving the men a good rest.

Saturday was a perfect day for the trial, as is evidenced by the photograph showing the *Minneapolis* on the course, where the only waves seen are those made by the ship herself.

The "Trial Board" detailed by the Navy Department to observe and report on the trial, assembled on board very early that day, while the special Board of engineer officers, nineteen in number, (four Chief Engineers and fifteen Passed Assistant and Assistant Engineers, with Chief Engineer A. W. Morley, U. S. N., as President, had joined the ship at Philadelphia, and had been observant passengers during the whole trip north.

The distance from the anchorage off Boston Light to the beginning of the course is about twenty-six miles, and during the run out the data takers were assigned to their several stations with such careful instructions as rendered the failure to obtain all the important data of the machinery performance almost impossible. The coal consumption, however, could not be obtained, and it is a lamentable fact that there are so many difficulties in the way of securing this very valuable item on all official trials of our ships. As it has no place in the contract, and does not influence the results, as far as the contractors are concerned, it is only through courtesy that arrangements can be made for measuring it. The practical objections are not trifling, especially where a ship has a long trip to make before reaching the trial grounds, as the picked coal must be weighed and bagged previously, and stored in the bunkers easiest of access from the fire rooms, and as near the doors as possible. Hence the coal used on the voyage to the grounds must be handled at a great inconvenience from more distant bunkers. Still there should be more interest shown in the matter by the builders, so that we could have a very accurate table of such results from all our ships, the value of such comparisons being sufficient to discount all the trouble incurred.

As there are three engine rooms and only two main-boiler compartments in the *Minneapolis*, the observers were stationed as follows: One chief engineer in each engine room to record the general conditions of running of the engines, the principal gauge readings and the counter. Of the assistants, one was stationed as time keeper and signal transmitter; one at each of the nine main cylinders for card taking; one in each lower engine room for data of the air and circulating pumps, temperatures, and speed of auxiliary machinery; and one in each of the boiler compartments to observe performance of the boilers, record speed of blowers and pumps, and to note the air pressure and the steam pressure at boilers.

The official trial consisted in a run over the course north, from Cape Ann to Cape Porpoise, a distance of 43.968 knots, a long turn at continued full speed, and a return trip over the course, the time actually on the course alone being considered. The signals for crossing the starting and finishing lines each way were transmitted electrically from the transit observer on deck to the time keeper in the engine room, who instantly repeated them by whistle. The error was thus very small, but constant and of the same sign, so that the elapsed times were very true.

The general instructions issued by Chief Engineer Morley may be well inserted here, and were as follows:

MEMORANDA FOR GUIDANCE OF OBSERVERS.—OFFICIAL TRIAL *MINNEAPOLIS*.

The official trial of the vessel will consist of two runs of about two hours each over a measured course, the two runs being separated only by the time necessary to make the turn.

For systematically recording the data of the machinery performance, the time on the course will be divided into sixteen periods of fifteen minutes each. These periods will be characterized by consecutive numbers beginning with the moment of commencement of *first run*, and in this no account will be taken of the turn: *i. e.* Period No. 1 is beginning of trial to fifteen minutes thereafter, and Period No. 9 will be beginning of second

run to fifteen minutes thereafter. The time of each period will be kept by an officer stationed for the purpose.

The system of signals for marking the periods is herewith given on a separate sheet.

Data will be recorded at the beginning of periods and entered in the books furnished. These books will be paged with numbers corresponding to the periods when records are made, and only such data as are called for in his assignment to station will be entered by each observer. The time, however, of each period will be copied in after the trial, and the book properly prefaced, signed and turned in. Steam pressure records in data book will be corrected after trial from tables furnished.

A complete set of main cylinder cards will be taken at the beginning of every *even number period*, 2, 4, etc., and from auxiliary machinery as called for in assignment to station. Separate cards will be used for top and bottom ends. These cards will each be marked with its *period* number and an index for top or bottom, and will be kept in an envelope previously and fully marked. All data for cards will be fully entered thereon as soon as practicable after the trial, and each card taker will be held individually responsible for the condition of any indicator used by him. Prior to trial he will satisfy himself that it is in readiness for obtaining good results, and after the trial he will turn it in clean and in good order, or with a note of any casualty happening to it.

Upon the conclusion of the trial, each engineer officer will forward to the Bureau of Steam Engineering a memorandum containing the results of his observations on the design, workmanship and general performance of the machinery and its details.

SIGNALS ON OFFICIAL TRIAL.

About five minutes before the beginning and end of each run over the course the annunciator in starboard engine room will be given a double swing, its gong being audible in all engine rooms.

At the exact *beginning* and *ending* of *each run* the annunciator of center engine will be similarly rung, these signals marking the

beginning of *Periods No. 1* and *No. 9*, as well as ending *Nos. 8* and *16*.

All other periods will be signalled as follows:

At one minute before the beginning of every period (except *Nos. 1* and *No. 9*,) the time keeper will sound a number of long and short blasts on a shrill whistle, and at the exact beginning of the periods he will sound one sharp blast on the same whistle.

The *warning* whistles for card-taking periods (even-numbered periods) will be given from the upper platform, but the "time" whistle will be sounded below like all others.

This proposed system was modified on the day of the trial by the Board, so that in lieu of using the annunciators, which would have distinctly marked the vital periods, the signals for the beginning and ending of the runs were transmitted by a push button on deck ringing a somewhat feeble electric gong in the upper engine room, and from there transmitted by whistle by the time keeper to the observers below, as before noted. There is no question regarding the desirability of having these particular signals made from the forward transit on deck directly to all the observers below, and this can readily be accomplished by an electrical connection which will ring simultaneously several large gongs situated where all data takers may easily hear them.

As the course was neared, the fire rooms were closed down and the forced-draft blowers started full speed. The engine throttles had been gradually opened out wide and the cut-off blocks run out to full gear on all links except the high pressure, which were kept slightly in on account of the steam pressure not being up to the limit, so that when at 9·44·15 A. M. the anxiously awaited signal "*start*" was given, the engines were running at an average of over 130 turns per minute, with steam only 146 pounds per square inch at the engines.

At this time, and indeed throughout the trial, the conditions in the engine room were such as to greatly gratify an engineer. The main engines appeared to be doing their work with the utmost ease, so smoothly and quietly did they keep the pace. Here and there a crosshead or crank pin journal would faintly be "marking centers," but their general working was admirable.

The regular oiling arrangements were wholly depended on and were entirely satisfactory, although, as is always done on trial trips, the supply was made excessive. Very light streams of water were also directed on some of the crank pins and crossheads as a precautionary measure, and in the vicinity of these points it was decidedly *rainy*.

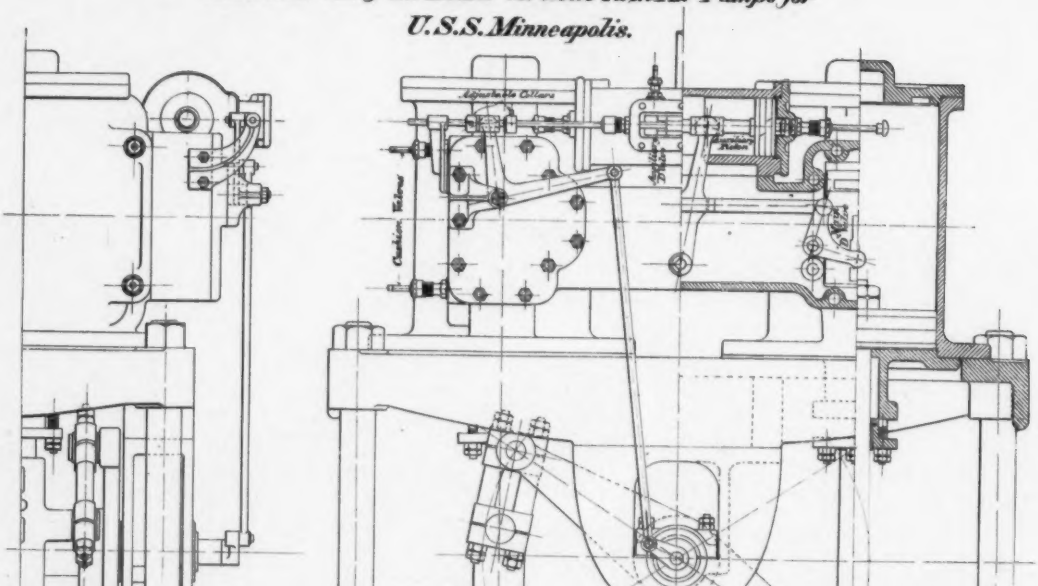
The high pressure crosshead journals of both the center and port engines showed a tendency to run warm, but were very readily controlled by the water service, while the starboard engine ran with scarcely a drop of water on any journal.

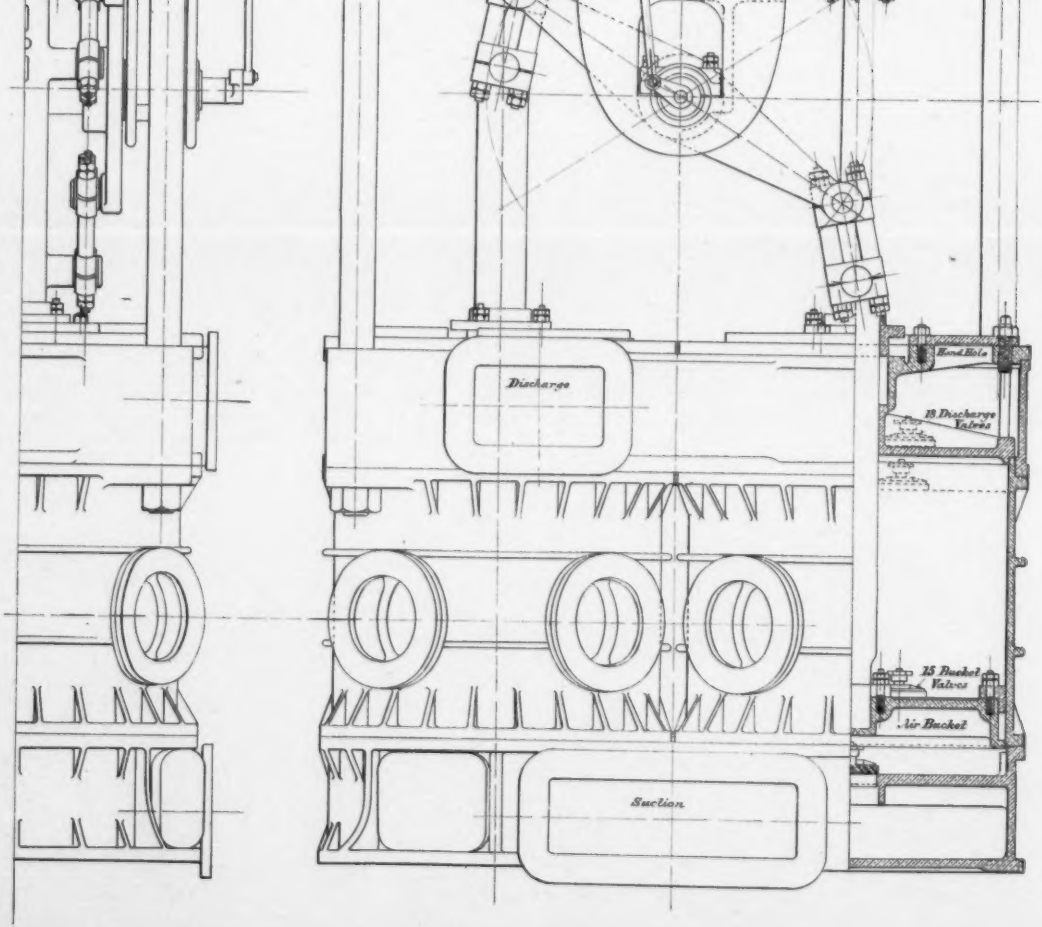
The light oiling galleries about the cylinders vibrated excessively, and gave at first glance a false impression of instability of the engines themselves, but close observation failed to show the slightest indication of structural weakness or lack of ample rigidity.

The contractors' engineers and oilers wore the usual full tarpaulin suits, and needed them, but throughout the trial these men were not called upon for any emergency duty, keenly alive though they were to discover the first intimation of a change in speed, or indication of the slightest disorder.

The operation of the main air pumps simply emphasized the justice of the claim of this class of pumps for highest honors. Not only did they do remarkably efficient duty at the smallest cost in power, but the regularity and certainty of their action, and their low speeds conduced to other efficiencies by reducing to a minimum all anxiety on the part of those in charge of the running of the machinery regarding their possible stoppage or breakdown, or of sudden and excessive change of speed. Those who have had experience with the crank air pumps (however well they may be made, in theory, to operate), cannot fail of comfort in the knowledge of the adoption of the Blake vertical twin-cylinder air pump for our latest cruisers. Here, at about only fifteen double strokes per minute, these pumps maintained a steady vacuum of over twenty-five inches, at a cost of but little more than 30 horse power for all three double pumps, and with the main engines aggregating over 20,000 horse power. This

Valve Gear etc. of the Blake Vertical Twin Air Pumps for U.S.S. Minneapolis.




Hand Hole
Discharge
15 Discharge Valves
15 Bucket Valves
Air Bucket
Suction

power of air pump is only about one-sixth ($\frac{1}{6}$) of one per cent. of the horse power of the main engines.

The operation of this pump differs from that of the "Duplex," where one pump engine drives the steam valve of its neighbor, as here the engine which drives the main steam valves has no other function to perform, and is adjustable to its work. The illustration shows the arrangement for this, which may be briefly described as follows: The beam which positively connects the main piston rods of the pumps, operates (from a point near its center, and by means of rod and bell crank) the slide valve of the horizontal cylinder which lies between the main steam cylinders. The piston of this horizontal cylinder is really the driving engine of the main cylinder steam valves, a function which it performs by means of a system of internal levers. All the ports are of fair size, and the operation of the pump is not only as positive as any Duplex, but is decidedly more regular and complete. The adjustable collars shown on the valve stem of the "valve driving engine" afford a means for regulating for a full stroke at any speed, while suitable cushion valves give a further control over the action during the stroke, in regulating distribution of work and preventing slamming of foot valves.

The circulating pumps were kept at about 190 revolutions per minute, and the bilge pumps were only used occasionally and at low speed.

In the fire rooms the scene was a busy one, yet not such as would at all impress one with an idea that the duty there was very onerous. The roar of the sixteen large Sturtevant blowers, running at an average of 540 revolutions per minute, and forcing into these compartments something like 160,000 cubic feet of air per minute, drowned all other noises there. The temperature was very comfortable, however, as the forced-draft system is the "closed fire-room" type. The atmosphere was somewhat charged with fine coal dust from the soft (Pocahontas) coal used, and the large number of firemen and coal passers crowded the spaces far more than ever would occur in service; but there was no confusion, and the boilers operated admirably, without any tendency

to prime, and with no indications of distress in any parts. The water in the glass gauges was perfectly steady, and only half the feed pumps (at the moderate speed of about thirty-one double strokes per minute) were required to keep up the supply. This, taken with the fact that the main boilers demanded about 2½ tons of feed water per minute during the run, is suggestive of the ample provisions made in the design for boiler supply in any emergency.

The auxiliary boilers (located above the protective deck) were used solely for operating the electric-lighting plant, and were, with the power developed by the dynamo engine, not considered in working out the results. These boilers are not in close compartments and cannot be forced.

There was a wide range of errors in the readings of the nineteen large-dial steam gauges connected with the main boilers and steam piping. Their records were duly corrected by comparisons with test gauges both before and after the trial, but this did not prevent their confusing indications being a constant annoyance to the attendants. The fault of unreliability seems to attach itself to all the large-diameter steam gauges that have been used with high pressures on these trials in recent years. Fortunately, each main boiler had a small auxiliary steam gauge, and these were approximately true, and, with the two test gauges fitted on the main steam pipes near the after boilers, were the guides relied upon. There was no danger, however, of exceeding the limit, as the engines were fully able to use all the steam possible to furnish with the one inch air pressure allowed in the fire rooms.

The uniformity in the speed of these engines on this trial was very remarkable, as the following table will show. On the *Columbia's* trial the wing engines ran considerably faster than the center engines, a fact which was not at all expected, but which led to the contractors' increasing the pitch of the side screws of the *Minneapolis* for her trial, making their pitch 22 feet, and that of the center screw 21 feet 6 inches, while the *Columbia's* screws were all set at 21 feet 6 inches.

REVOLUTIONS FOR FIFTEEN-MINUTE PERIODS ON OFFICIAL TRIAL.

Periods.	Center Engine.	Stbd. Engine.	Port Engine.	Mean.
1	130.9	127.3	132.3	130.2
2	129.3	129.3	130.7	129 8
3	132.3	132.	133.5	132.6
4	132.9	132.7	132.5	132.5
5	132.1	132.	134.6	132.9
6	132.1	132.	133.1	132.4
7	132 5	132.	133.5	132 7
8*	132 4	133.7	133.9	133.9
9	134.3	134.3	134.8	134.5
10	133.5	133.3	134.2	133.7
11	132.7	132.7	132.8	132.7
12	132.9	133.3	133.9	133.4
13	132 5	132.	132.9	132.5
14	133.5	132.7	133.	132.1
15	129 6	130.7	132.7	131.
16*	131.6	131.7	130 6	131.3

*Not full fifteen-minute periods.

A word as to the vibration of the ship:

There were two distinct sets of vibrations. First, longitudinal athwartship vibrations which reached a maximum at from 90 to 95 revolutions per minute of the engines, and which were imperceptible at higher or lower speeds. Second, vertical vibrations, which began to appear about 120 revolutions per minute; at 128 revolutions the amplitude grew rapidly; no diminution was detected at the highest speeds reached, about 133 revolutions, though it is probable that these vibrations reached a maximum at about this point. It was also noted that the bow, the stern, and a position nearly amidships were points of maximum vibration, and that at intermediate points the amplitudes were very much less.

In amount, the vibration was greater than that in most of the ships previously tried, probably greater than in the case of the *Columbia;* and approaching that found on some of the Liners at full speed.

The change in trim due to speed was about eleven inches.

The time on the course for the first run was 1 hour 55 minutes 18.46 seconds, and the long turn (during which the throttle and links of main engine were unaltered), occupied 18 minutes

and 34 seconds. The run back was accomplished in exactly 1 hour 53 minutes 43.82 seconds, not only without a mishap, but with apparently increasing facility, and it was not until several minutes had elapsed after the finish that the blowers were stopped and fire rooms opened. The ship continued at a high speed back to the anchorage.

TIMES OF PASSING STATIONS.

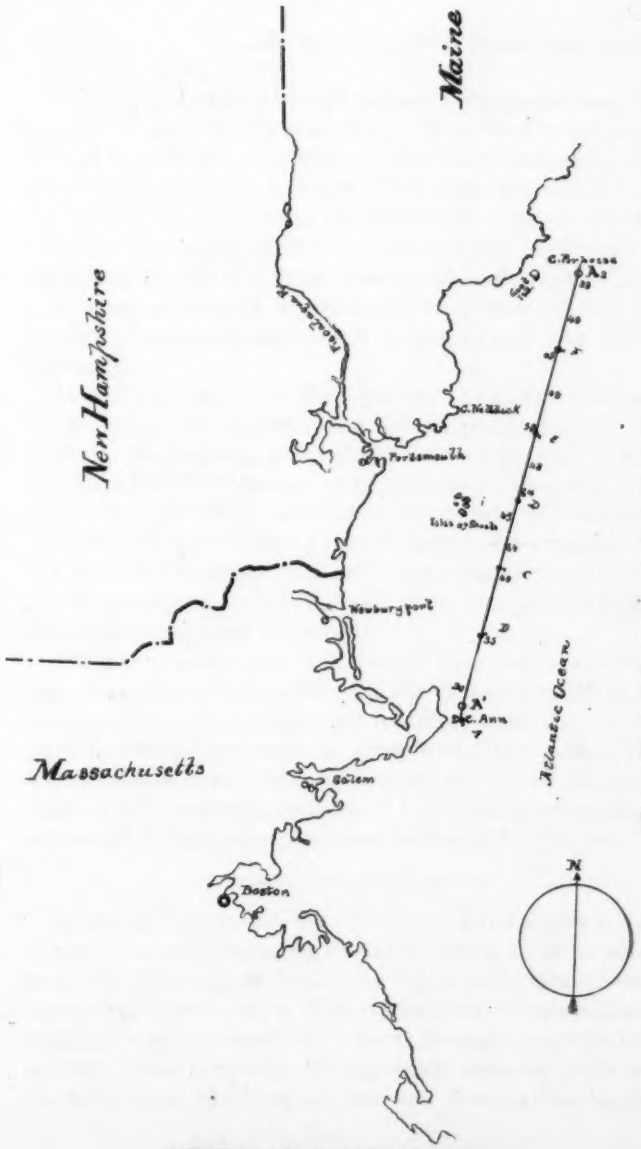
Run North.

Stations.	Time of passing.			Elapsed time in minutes.	Distance, knots.	Speed, knots.
	h.	*m.*	*s.*			
A	9	44	14.46	.....	.....	.....
A 1	9	50	39.56	6.42	2.373	22.19
B	10	09	15.02	18.59	6.818	22.01
C	10	26	05.92	16.85	6.647	23.66
D	10	43	28.98	17.38	6.566	22.67
E	10	59	21.13	15.87	6.295	23.80
F	11	21	14.48	21.89	8.182	22.43
A 2	11	39	32 92	18.31	7.087	23.22

Run South.

Stations.	Time of passing.			Elapsed time, minutes.	Distance, knots.	Speed, knots.
	h.	*m.*	*s.*			
A2	11	58	06.66	.....	.....	.....
F	12	15	57.80	17.85	7.087	23.82
E	12	37	21.61	21.40	8.182	22.94
D	12	53	05.15	15.73	6.295	24.01
C	1	10	41.73	17 61	6.566	22.37
B	1	27	29.81	16.80	6.647	23.74
A1	1	45	41.92	18.20	6.818	22.48
A	1	51	50.48	6.14	2.373	23.19

The distance each way on the course being 43.968 knots, the total trial distance was 87.936 knots, and the total time on course 3 hours 49 minutes 02.28 seconds. A tidal correction of .14139 knots was calculated by the observers on the vessels stationed along the line, as an amount to be added, making the official



OFFICIAL TRIAL COURSE

mean speed of the *Minneapolis* 23.073 knots, and the bonus earned $414,600.

This big premium is no *gift* to the contractors, as many inland calamity howlers try to make the public believe, but it is a well-earned sum which is represented in the difference between a good ship and an almost perfect one. The writer has been a constant observer of the building of the *Minneapolis* from its very beginning, and is convinced that the phenomenal results are to be attributed to nearly faultless workmanship throughout, and no long head is required to appreciate the money value in the resultant guarantee of economical endurance and long-continued efficiency.

In this particular case, the repetition of the first success with triple screws is a special reason for congratulating the Bureau of Steam Engineering, placing as it does the adoption of the system for which that Bureau is happily responsible, beyond even a shadow of doubtful expediency, but it may well believe that the designed speed would not have been so far surpassed had it not been for the ability, skill and extraordinary care which governed the expansion of the details of the design, and especially their final fittings and adjustment.

While it is noted that the greatest speed was made over the same divisions of the course each way (between Stations E and D) it is impossible to assert that in deeper water the ship would have increased her record, as there is no direct evidence as to the absolutely exact distances between the several intermediate stations at these times; and at such high speeds, minute fractions of time or distance would account for marked variations.

COAL CONSUMPTION TRIALS.

During the return trip from Boston to Philadelphia it was the intention to make some careful experiments in order to determine the efficiency of propulsion when using one screw, two screws and three screws. The instructions to this end were to maintain a regular speed of 12 knots for eight hours under each of these three conditions, during which indicator cards were to be taken from the main engines and principal auxiliaries, all

data recorded, and the coal used carefully weighed. Owing to exceedingly foggy weather which necessitated the frequent stopping or slowing of the ship to take soundings, it was impossible to secure data of any real value. The indicator cards were too small for accurate measurement, a sufficient number of light springs not having been provided for the indicators against this emergency, and the coal consumption was no index of that which would be burned on a regular uninterrupted run at a steady speed. During these trials, the screw shafts of the unused engines were uncoupled and allowed to revolve freely.

HELM ANGLE AND TACTICAL DIAMETER.

Trials were also made to determine the helm angle necessary to keep the ship in a straight course when using only one side screw, the other screws revolving freely. The results were very similar for both starboard and port screws, being a helm angle of 6.5 degrees, with the engine running at 90 revolutions, corresponding to a speed of between 12 and 13 knots.

In determining the tactical diameter with all three engines running, speed about 20 knots and helm hard aport, the ship turned through 16 points in 2 minutes 45 seconds. The diameter of the circle was 700 yards, or 5.15 times the length of the ship. The heel was less than one degree.

CONTRACTOR'S ENGINEER FORCE ON TRIAL TRIP *MINNEAPOLIS*.

6 Engineers.
8 Water tenders.
8 Stokers.
2 Night engineers.
44 Engine room oilers.
64 Day firemen.
48 Day coal passers.
16 Night firemen.
8 Night coal passers.
3 Spare firemen.
3 Spare coal passers.
10 Messmen.

2 Storekeepers.
1 Time keeper.
10 Machinists.
2 Riggers.
4 Boiler makers.
1 Carpenter.

240

GENERAL DESCRIPTION.

The *Minneapolis* was designed by the Navy Department, which furnished general plans and specifications for hull and machinery to the contractors and builders, the Wm. Cramp and Sons Ship and Engine Building Company, of Philadelphia, Pa., the expansion of these general designs into exact details, together with the piping systems and location of the auxiliary machinery, being done by the contractors, and their drawings submitted to the Bureaus concerned before work was begun. In the case of the machinery alone, this necessitated the making of some 300 separate drawings, a fact which indicates in a way the magnitude of the task. The contract was signed August 31, 1891, (Secretary of the Navy, B. F. Tracy,) the price for the ship complete being $2,690,000, with a bonus and penalty clause as before noted.

The first keel plate was laid December 16, 1891, and the vessel was launched August 12, 1893.

The weight of the machinery was limited to 2,000 tons (about one-tenth of a ton per designed horse power), which weight included water in the boilers, and in condensers, pumps, pipes and stern tubes, but did not include weight of stores, heating apparatus, spare parts, tools in workshop, capstan, windlass, steering gear or winches. At the time of the trial this "included" weight amounted to 1961.8 tons, leaving ample margin for escaping another penalty which the contract imposed on overweight, and which was $500 per ton up to 5 per cent., beyond which an additional $10,000 was to be attached.

The type of the ship is a protected cruiser, or commerce destroyer, 412 feet long and 58 feet beam, with a normal draught

of 24 feet. The hull is of mild steel, the skin being of but a single course of 22½-pound plating (about ⅞-inch thick). There is a double bottom divided by water tight floors into 17 compartments, which extend across the ship through lightening holes in the keel. Besides these, there are 198 other water tight compartments below the gun deck. A protective deck covers the hull proper from stem to stern. This is made of two courses of 1¼-inch nickel steel, to which, on the slopes over the machinery spaces, another course 1½ inches thick is added, making 4 inches of steel where most needed. This protective deck joins the vessel's sides at 4 feet 6 inches below the normal water line, and "crowns" one foot above that water line.

A coffer dam 5 feet thick and 7 feet 6 inches high extends the entire length of the ship's sides and rests on the protective deck slopes. It is filled with compressed cellulose.

There is a steel conning tower forward, five inches thick, in which are placed improved appliances for the control of the ship's movements, and for securing a continuous ocular knowledge of the speed and direction of the engines and the position of the helm.

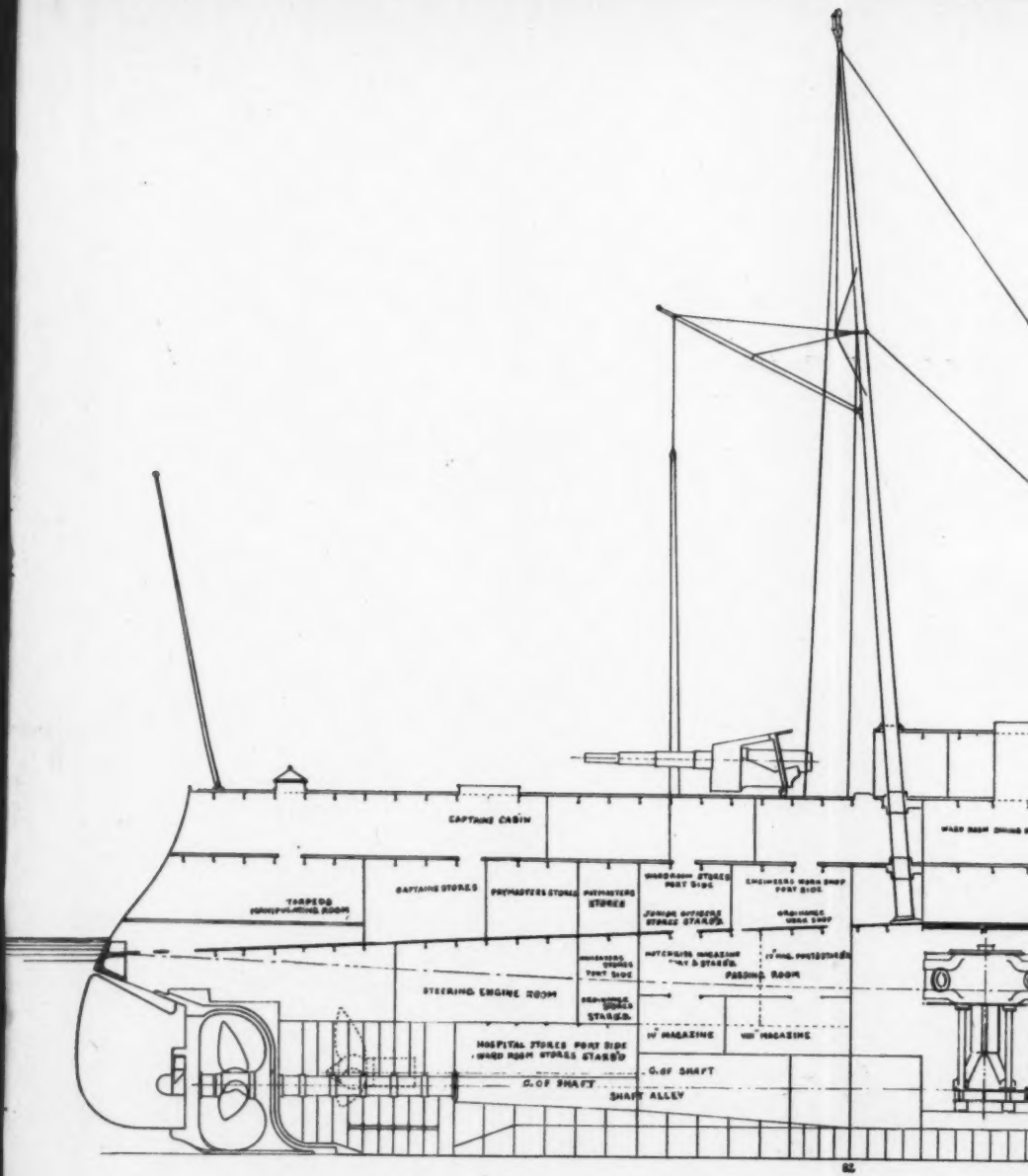
The main boiler compartments are not divided longitudinally, and are the largest compartments below the protective deck, the forward one being 67 feet long and the after one 69 feet. The engine compartments occupy a total length of 76 feet, excluding shaft alleys, making 212 feet in length of the hull for the machinery proper, or about half the entire length of the ship.

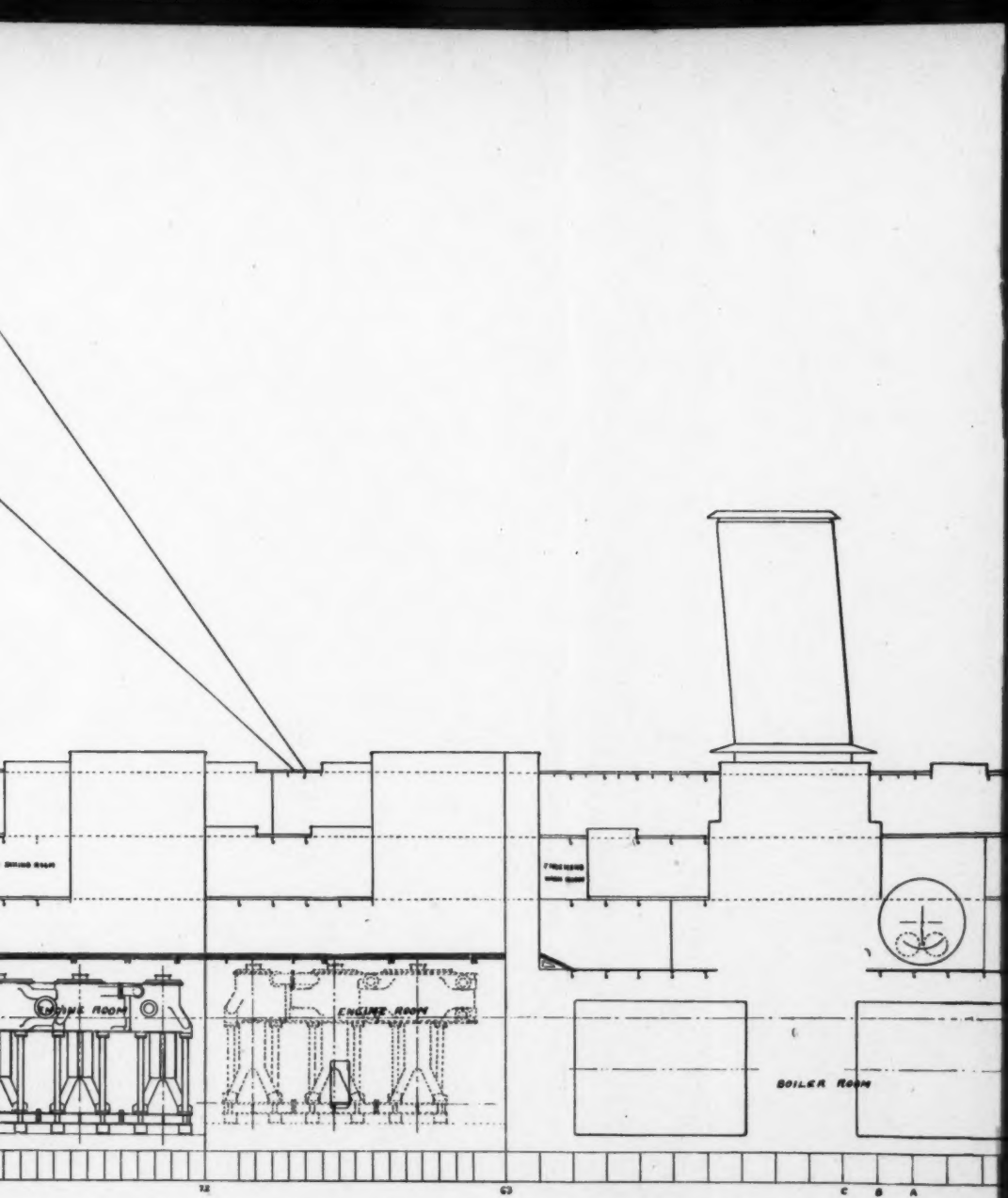
There are only two main smoke-pipes, (instead of four, as on the *Columbia*) and this is the distinctive difference between these two vessels in outward appearance.

Beside the commanding officer's quarters, there are rooms fitted up for the accommodation of eighteen ward-room officers, eight junior officers, and three warrant officers, and there is berthing space for four hundred and seventeen petty officers, crew and marines.

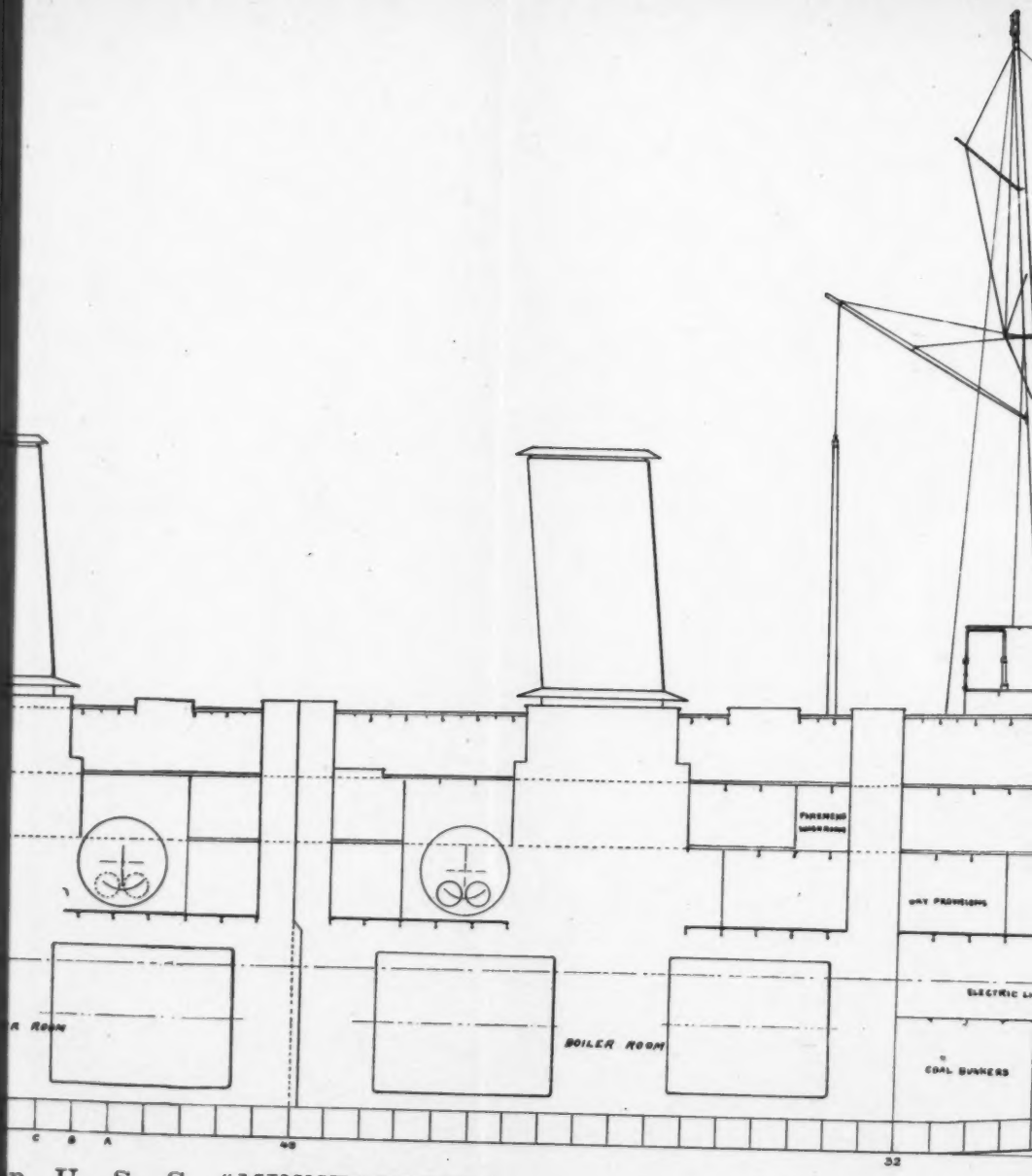
The boats carried are as follows:

One 33-foot steam cutter; one 30-foot steam cutter; one 32-foot launch; three 28-foot cutters; two 24-foot cutters; one 30-

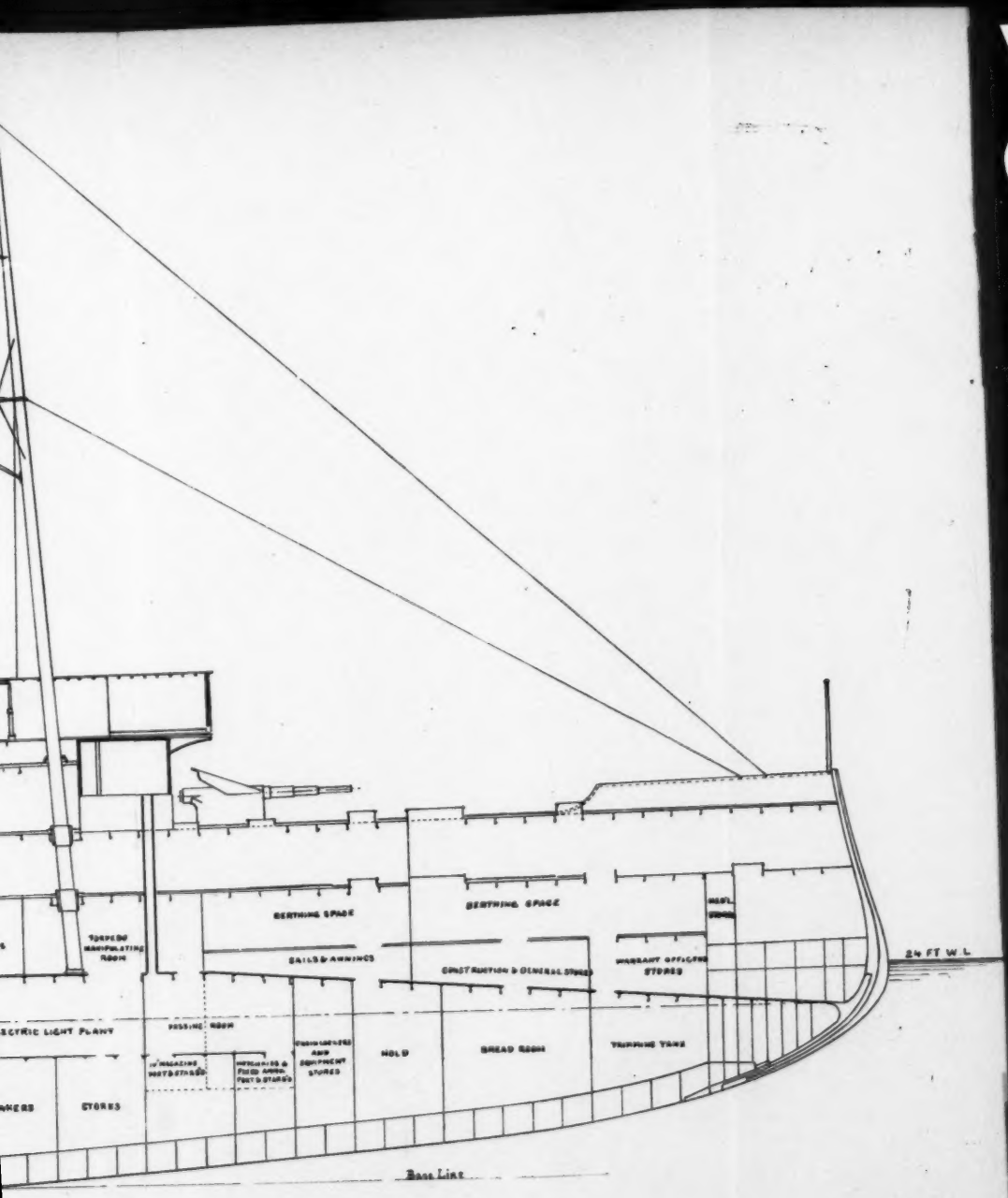

CAPTAINS CABIN
TORPEDO
CAPTAINS STORES
PAYMASTERS STORES
PAYMASTERS STORES
PASSAGE
STEERING ENGINE ROOM
HOSPITAL STORES PORT SIDE
WARD ROOM STORES STARBD
C. OF SHAFT
C. OF SHAFT
SHAFT ALLEY



Longitudinal Section U. S. S.



n U. S. S. "MINNEAPOLIS."


BERTHING SPACE
BERTHING SPACE
TORPEDO MANIPULATING ROOM
SAILS & AWNINGS
CONSTRUCTION & GENERAL STORES
WARRANT OFFICERS' STORES
24 FT W.L.
ELECTRIC LIGHT PLANT
MESS ROOM
MAGAZINE
SHELL ROOM
HOLD
BREAD ROOM
TRIMMING TANK
STORES
Base Line

foot gig whaleboat; one 29-foot whaleboat; one 30-foot barge; one 20-foot dinghey.

These boats are all stowed inboard on the superstructure deck.

ARMAMENT.

1 8-inch (40 caliber) rifle—forward.
2 6-inch (40 caliber) rifles—aft.
8 4-inch rapid fire guns, in 4-inch sponsons—gun deck.
8 6-pounder rapid fire guns, in 2-inch sponsons—gun deck.
4 6-pounder rapid fire guns, on upper deck.
4 Gatling guns.
4 1-pounder rapid fire guns.
2 torpedo tubes, on bows.
2 torpedo tubes, on quarters.

HULL.

Length between perpendiculars, feet and inches	411- 7
Length on L.W. L., feet and inches	411- 7
Length over all, feet and inches	414-10
Beam, feet and inches	58- 2
Ratio of length to beam	7.08
Depth of hold, top of floors to top of main deck beams, feet and inches.	37- 3
Draught, mean, sea going trim (normal), feet	24
Trim	0- 0
Displacement (normal)	8,005.
Tons per inch, L.W.L	37.2
Area of immersed midship section, L.W.L., square feet	1,212.
Area of L.W.L. plane, square feet	15,600.
Center of gravity of L.W.L. abaft midship section, feet and inches	4- 8½
Center of buoyancy above base (bottom of keel), feet and inches	14- 1½
Center of buoyancy abaft midship section, feet and inches	2- 3½
Center of gravity above base, feet and inches	21- 8
Transverse metacenter above center of buoyancy, feet and inches	10- 7
Longitudinal metacenter above center of buoyancy, feet	458.
Transverse G.M., "metacentric height," feet and inches	3- ½
Longitudinal G.M., feet	450.
Block coefficient for displacement	.491
Cylindrical coefficient for displacement	.566
Midship section coefficient	.869
L.W.L. coefficient	.652
Wetted surface to L.W.L., square feet	28,923.
Number of frames	109.
Number of water tight compartments below gun deck, and including double bottoms	215.

The tabulated data of performance on contract trial is appended, following the description of the machinery.

Main Engines.—There are three similar sets of main engines, each set in a separate water-tight compartment, the center engine room being abaft the starboard and port engine rooms, which are abreast of each other, as shown in the illustration. The type of engine is the inverted, direct acting, three-cylinder triple-expansion. The housings, or supports, are for each cylinder an inverted cast steel Y frame at the back, and two 8-inch forged hollow steel columns in front. The valves are all of the single ported piston type, there being one for each high pressure cylinder, two for each intermediate, and four for each low pressure cylinder. The link motion is of the Stevenson type, double bar. Independent adjustable cut-off blocks are fitted to each link, with a range from .44 to .74 of stroke. There is a steam float lever reversing gear, which can also be adjusted to work by hand pump and oil, there being a common piston rod for both steam and oil pistons and cylinders. The operation of reversing by steam is nearly instantaneous.

The turning engine is a double inverted simple 8 by 6 engine operating a worm shaft and gear made to readily engage in a worm wheel secured to the coupling on the crank shafts between the intermediate and low pressure sections.

The high pressure valve takes steam in the center through a 15-inch steam pipe. It exhausts at ends to the intermediate valves through four short 14 inch bends, (two on each side) which pipes form the first receiver. The intermediate valves exhaust from the center through a single 23-inch pipe (reducing to a long 19-inch pipe between the two ends of the low pressure cylinder), this forming the second receiver. The low pressure valves exhaust to the main condenser from the center through two 22½-inch pipes. The main steam pipe from the boilers to the engines is of lap welded steel, ⅜-inch thick and 20 inches in diameter as far as the first engine branches. (See illustration.)

As this machinery (barring the larger boilers) is a duplicate of that of the *Columbia*, much of the minutely detailed description of the latter so carefully prepared by Passed Assistant Engi-

neer Thos. F. Carter, U. S. N., and published in Vol. VI., No. 1, of this JOURNAL, will be omitted from this paper, as it is there available for use of any who desires to enter more fully into this matter than they are enabled to do by the principal dimensions and data here presented.

DATA OF ONE MAIN ENGINE.

Number of cylinders		3
Diameter of cylinders, inches	H.P.	42
	I.P.	59
	L.P.	92
Stroke, inches		42
Diameter of valves, inches	H.P. (one)	18
	I.P. (two).	23
	L.P. (four)	21
Diameter of piston rods (all), inches		8⅛
Length of connecting rods, center to center, inches		84
Distance between centers of cylinders, feet and inches		9–7½
Volume swept by pistons per stroke, cubic feet, mean	H.P.	33.04
	I.P.	65 82
	L.P.	160.94
Volumetric cylinder clearance (mean of the two ends) cu. ft.	H P.	6.36
	I.P.	8 64
	L.P.	21.43
Ratios of net areas of pistons	H.P. to I.P.	1.99
	I.P. to L.P.	2.44
	H.P. to L.P.	4.87
Crank pins	Diameter, inches	17
	Length, inches	21½
	Axial hole, diameter, inches	8½
Crank shaft, two bearings each section	Length (each section) feet and inches	9–7½
	Diameter, inches	16
	Length each bearing, inches	19⅝
	Axial hole, diameter	7½

This volumetric clearance was obtained by fluid measurement, and will be of interest to the advocates of the slide valve for low pressure cylinders.

Shafting.—The crank shafts are interchangeable, there being a separate section for each crank. The thrust and propeller shafting is 15¾ inches diameter and the axial hole 7½ inches, tapering to 4½ at propeller ends. The center shaft runs parallel

to the keel, while the wing shafts are inclined upwards at about 1 foot 11 inches in 100 feet, and also inclined outwards at about 3 feet 10¼ inches in 100 feet from the center line. This brings the position of the center of each wing propeller 13 feet 5 inches forward, 3 feet 3 inches above, and 12 feet 5 inches outboard of that of the center screw. The lines of the wing shafts if projected would meet at about 4 feet 9 inches above the base line, and 156 feet forward of the center of gravity, between frames No. 16 and No. 17. Each engine has a thrust bearing of the horse-shoe pattern, fitting 11 collars turned on the thrust shafts. These collars are 3¾ inches deep and 2 inches thick. The thrust surface of each shaft is 2,527 square inches.

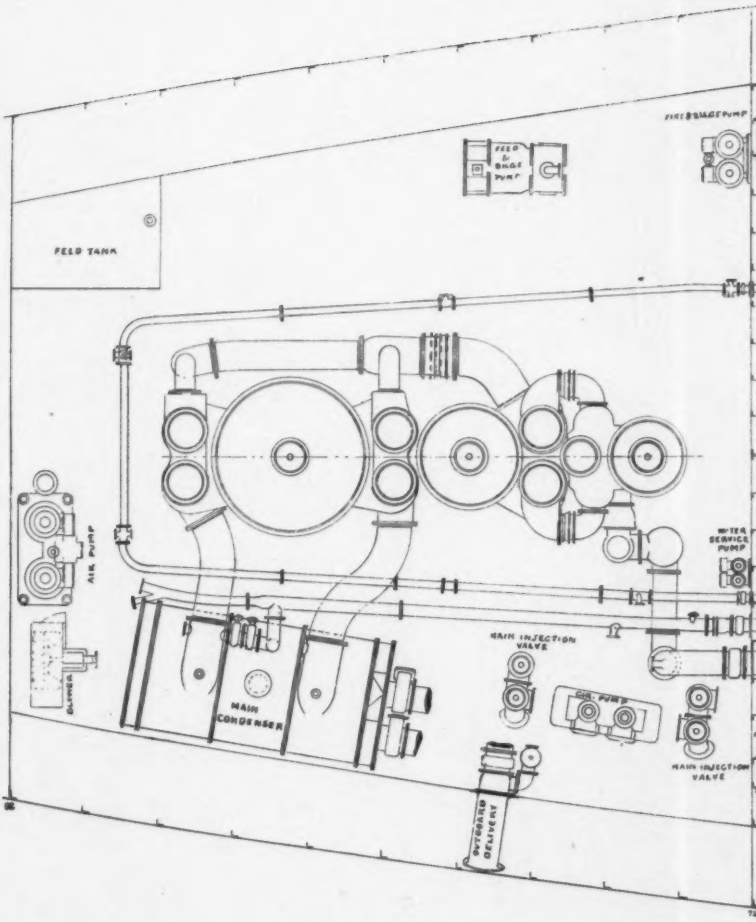
Main Condensers.—There is one main condenser in each engine room. They are cylindrical, and made of composition throughout, 14 feet 9 inches long and 6 feet 7 inches diameter. Steam is outside of tubes.

Number of tubes in one condenser	4,894
Length between tube sheets, feet and inches	11–10
Diameter of tubes, outside, inch	⅝
Cooling surface one condenser, square feet	9,474
Cooling surface, three condensers, square feet	28,422
Ratio total cooling surface (three condensers) to total H.S. of eight main boilers	1 to 1.69
Aggregate exposed length of all condenser tubes in miles	32.9

Main Air Pumps.—There are three double main air pumps (Blake vertical inverted twin cylinder).

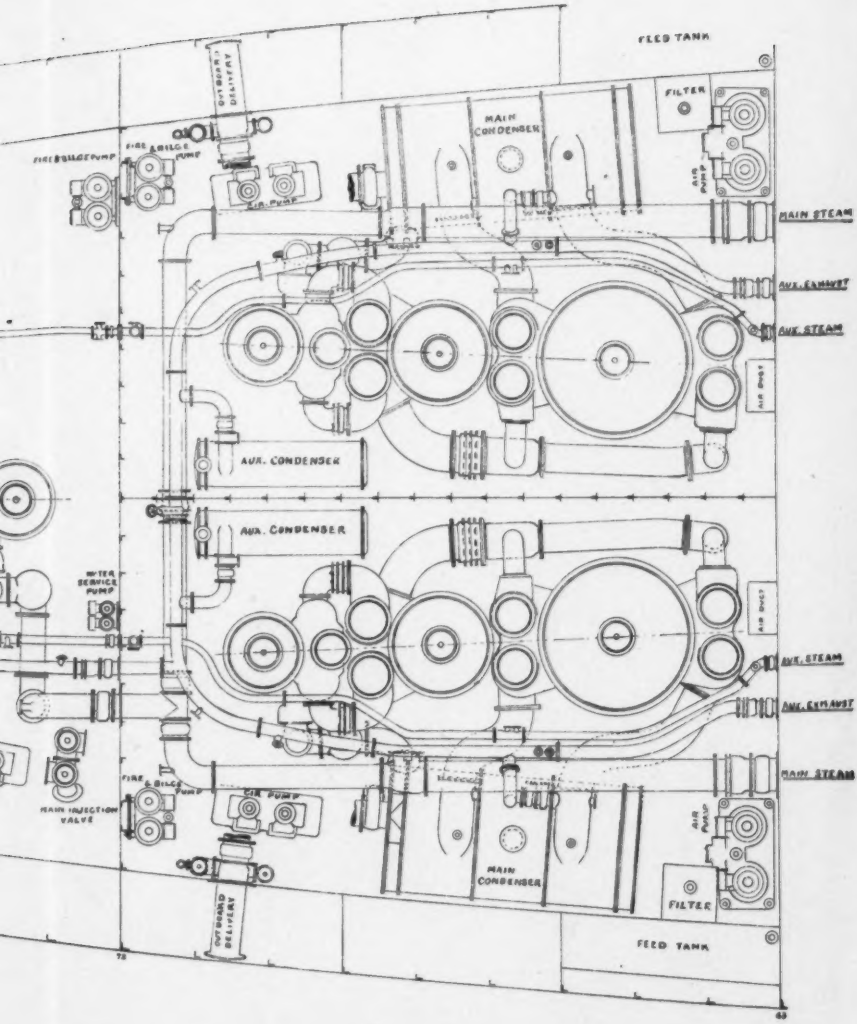
Diameters, steam cylinders, inches	16
pump cylinders, inches	31½
piston rods, inches	3
pump rods, inches	5
Stroke, inches	21
Ratio of volume swept by L.P. piston (one main engine), to that of two air pump buckets per stroke	8.6 to 1
Volume swept by two air pump buckets per stroke (mean), cubic feet	18.7

Main Circulating Pumps.—There are two centrifugal pumps for each main condenser, driven by two 10 inch by 6 inch simple engines coupled together. These pumps are also con-



ARRANGEMENT OF MAIN & AUX. STEAM &

U. S. S. MINNI



STEAM & EXHAUST PIPES IN ENGINE ROOMS

S. MINNEAPOLIS

nected to draw from the bilge and main drains, and their discharge may be direct overboard, if desired, without its passing through the condensers. The capacity from the bilge is 6,750 gallons per minute for each pump, aggregating 40,500 gallons per minute for the six pumps and about equalling an amount of water which would enter through a 27-inch hole in the ship's bottom.

Other Pumps.—Of the other steam pumps in the ship, there are eleven with bilge connections having an aggregate capacity of 7,400 gallons per minute, which added to that of the circulating pumps makes a grand total of 47,900 gallons per minute.

LIST OF STEAM PUMPS.

Purpose.	Type.	Location, room	Suction from	Gals. per minute.
3 main air pumps.....	Vertical-twin.	Engine.	Condensers.	.....
6 main circulating.....	Centrifugal.	Engine.	Sea and bilge.	6,750
4 main feed.....	Vertical duplex.	Main boiler.	Feed tanks.	475
4 auxiliary feed.....	Vertical duplex.	Main boiler.	Sea, tank, bilge or boilers.	475
2 aux. boiler main feed	Vertical duplex.	Aux. boiler.	Feed tank.	100
2 aux. boiler aux. feed	Vertical duplex.	Aux. boiler.	Sea or tanks.	100
3 fire and feed.....	Horizontal duplex.	Engine.	Sea, tank or bilge.	750
3 fire and bilge.....	Vertical duplex	Engine.	Sea or bilge.	750
3 water service.....	Vertical duplex.	Engine.	Sea.	150
3 aux. condr. A. and C.	(Combined), single.	Engine.	Sea and cond'rs.	500
1 wrecking.....	Horizontal, single.	Distiller.	Main drain.	1 000
1 evap. feed and tank.	Horizontal, single.	Distiller.	Sea and filter.	50
1 evaporator brine.....	Horizontal, single.	Distiller.	Evaporators.	40

The pumps connected with the evaporators are of Davidson pattern; all the others are of Blake design except the air and circulating pumps on auxiliary condensers, which are Knowles.

Screw Propellers.—These are of the modified Griffith design, true screw, three bladed, with adjustable pitch ranging from 19 feet 6 inches to 22 feet. The material is manganese bronze, and the diameter of the hubs is about one-third the diameter of the wheel. The center and starboard screws are right hand and the port screw is left hand. The center screw is 14 feet in diameter, while the wing ones are one foot greater, although the helicoidal area is kept about equal by widening the blades of the former.

	Wing Screws.	*Center Screw.*
Diameter of propeller, feet	15	14
Diameter of hub, feet and inches	4–11½	
Pitch as set, feet and inches	22–0	21–6
Helicodal area one propeller, square feet	53.7	53 28
Disc area one propeller, square feet	176.7	153 9
Ratio pitch to diameter (as set)	1.46 to 1	1.55 to 1
Immersion of upper edge of blades (normal draught), feet and inches	5–5	9–1

Each blade weighs about 3,900 pounds, or 11,700 pounds for the blades of each screw, and each hub about 7,200 pounds, making nearly 19,000 pounds for each propeller complete.

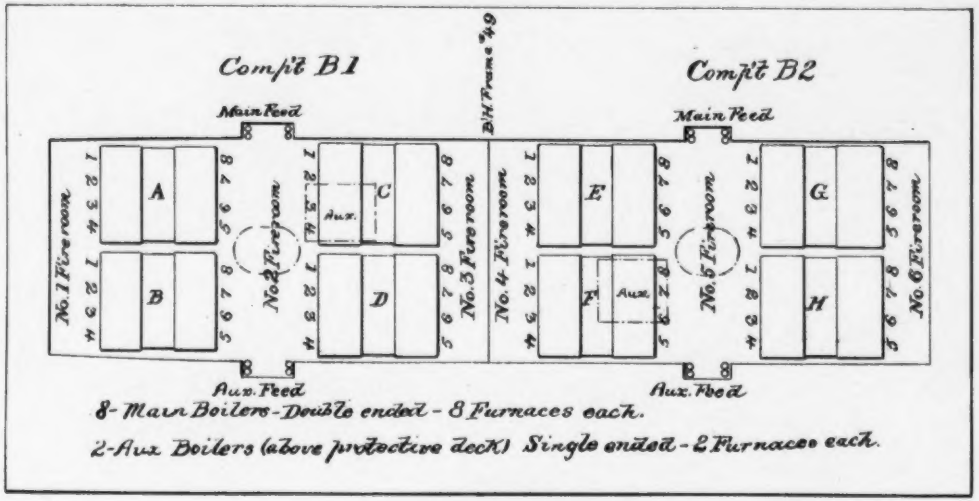
Boilers.—There are eight main and two auxiliary cylindrical boilers, placed as shown in the accompanying illustration. The six after main boilers are the largest of modern marine types, being 15 feet 9 inches in diameter and 20 feet long—two feet longer than the largest boilers in the *Columbia*, though of the same diameter. The other boilers are similar to the *Columbia's*, but by reason of the increased size of the above six the total heating surface of the main boilers is 48,194.54 square feet, and the total grate surface 1,456.2 square feet, against 43,268.13 and 1,344 square feet respectively for the *Columbia*. This greater boiler power is the only important difference in the machinery of the two ships. Each of these larger main boilers weighs about 72 tons empty and without fittings, and contains about 40 tons of water at steaming level. All the main boilers have flat ends, but the auxiliary boilers have the ends curved back at the top to a radius of 2 feet 2½ inches. The latter boilers are in separate open fire rooms on the protective deck.

The Cone patent rocking grate is used in all the furnaces.

The main boilers are double ended with four furnaces at each end. The two adjacent furnaces on each side of each end have a common combustion chamber. The auxiliary boilers are single ended and have but two furnaces each. All the furnaces are of corrugated steel. The main boiler shells are in three lapped courses, with three sheets in each course, butted, and strapped inside and out.

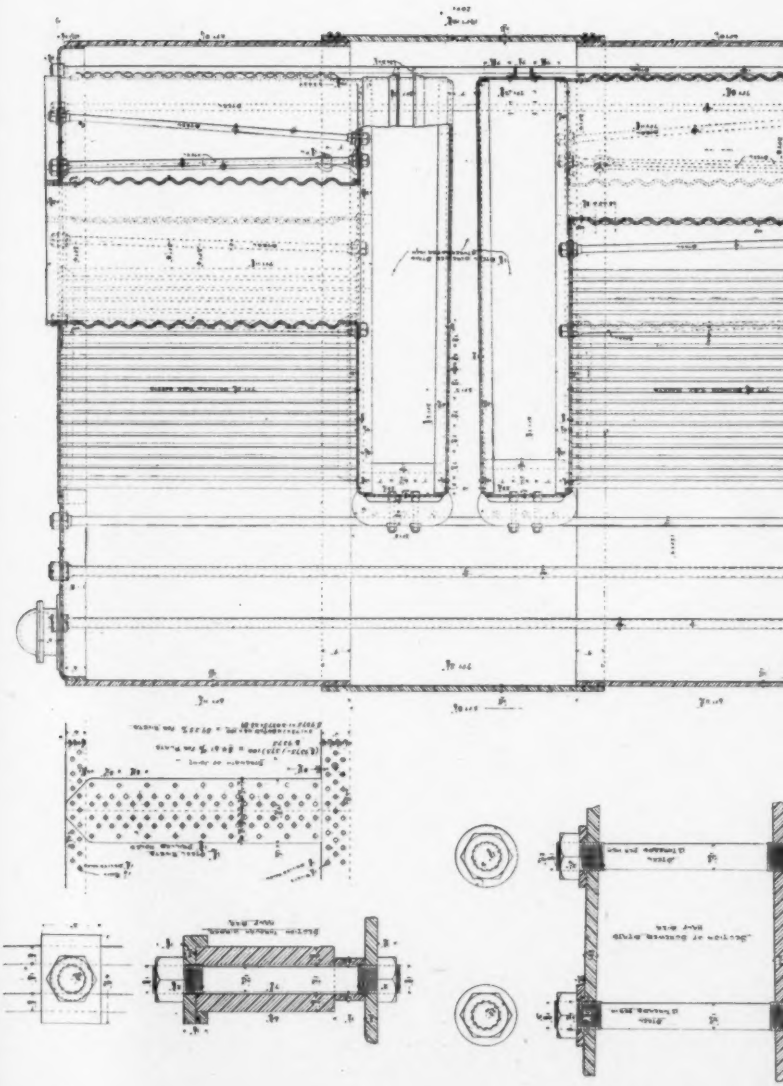
There is one quadruple safety valve (each valve four inches in

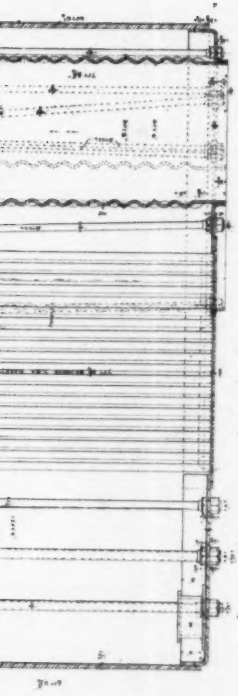
ARRANGEMENT OF FIREROOMS

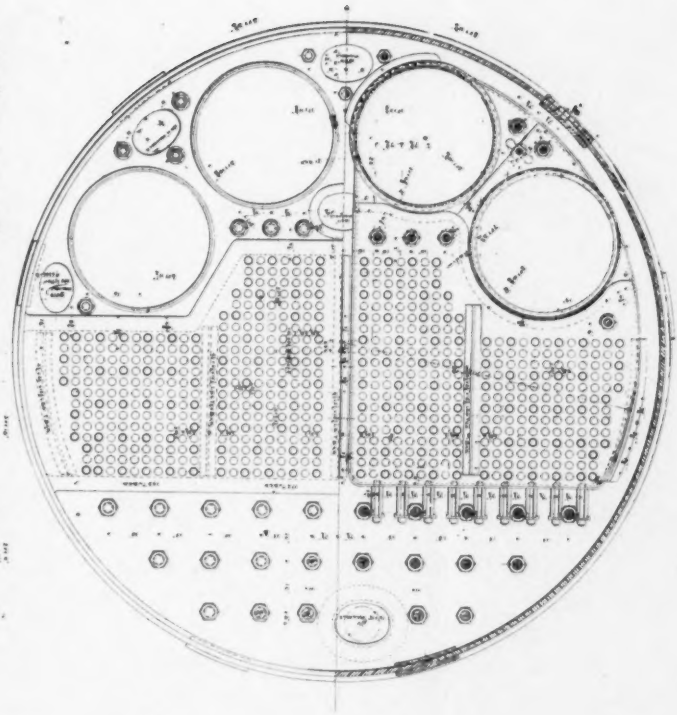


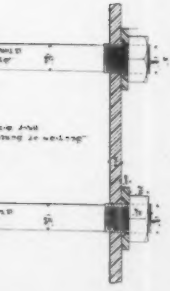
Protective Deck

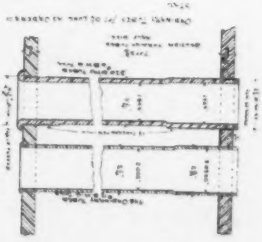
U. S. S. MINNEAPOLIS











diameter), on each main boiler, and these, as well as the stop valves, can be operated from the berth deck.

Hydrokineters are fitted for primary circulation, and injectors from part of each internal feed pipe, with suction branches to the bottom of the boilers, the combined feed and "circulated" water being discharged near the water level through down-pointing branches well distributed. This is a most efficient and durable device, and is one great and direct cause of freedom from leaky tubes and joints on these trial trips and in service.

All the material is mild steel, including the tubes. The latter were rolled by the Reading Iron Co. from open-hearth steel especially made for the purpose by the Pottstown Iron Co., and are most excellent in finish and quality.

The main smoke-pipes, two in number, are flat sided, with semi-cylindrical ends, the section being 13 feet long by 9 feet 6 inches wide. These pipes are 70 feet high (from grate level), and in the center of each runs the smoke-pipe of one auxiliary boiler, 29 inches diameter, held in place by straps and brackets.

MAIN BOILERS—DATA FOR ONE BOILER.

	Six after.	Two forward.
Shell, Length, feet	20	18
Diameter, feet and inches	15–9	15–3
Thickness, inches	$1\frac{1}{32}$	$1\frac{1}{64}$
Number courses	3	
Sheets in course	3	
Furnaces, Number	8	
Diameter (least inside), inches	40	39
Diameter (greatest inside), inches	$42\frac{7}{8}$	$41\frac{15}{16}$
Thickness, inch	$\frac{9}{16}$	$\frac{17}{32}$
Length of grates, inches	84	78
Number of grate bars each furnace	7	
Tubes, Number of ordinary No. 12, B.W.G.	948	784
Number of stay No. 6, B.W.G	320	288
Diameter all tubes outside, inches	$2\frac{1}{4}$	
Length between tube sheets, inches	$87\frac{3}{4}$	78
Center to center of tubes vertically, inches	$3\frac{1}{4}$	
Center to center of tubes horizontally, inches	$3\frac{1}{2}$	
Internal diameter ordinary, inches	2.032	
Internal diameter stay, inches	1.844	
Thicknes of tube sheets, inch	$\frac{9}{16}$	$\frac{17}{32}$
Thickness of heads, inch, top	1	
bottom	$\frac{3}{4}$	

	Six after.	Two forward.
Tube-heating surface, square feet	5,539.89	5,104.15
Plate-heating surface, furnaces, square feet	363.	295.42
Plate-heating surface, combustion chambers, square feet	498.	495.04
Total heating surface, square feet	6,400.89	5,894.61
Grate surface, square feet	186 7	168.
Ratio G.S. to H.S	1 to 34.29	1 to 29.13
Area through tubes, square feet	27.3	23.
Steam space, normal, cubic feet	923.3	634.

TOTALS MAIN BOILERS.

Heating surface, square feet	48,194.54
Grate surface, square feet	1,456.2
Area through tubes, square feet	209.8
Volume steam space, cubic feet	6,806.6
Area water surface, square feet	2,060.6
Net area two main smoke-pipes, square feet	196.
Aggregate length (exposed) of all tubes *in miles*	12.7

RATIOS.

Total G.S. to H.S	1 to 33.09
Area through tubes to G.S	1 to 6.94
Cubic feet steam space per square foot G.S	4.67 to 1.

FORCED DRAFT.

Sixteen 60-inch Sturtevant blowers are used for this purpose, two blowers being placed in front of each end of each main boiler overhead, drawing air through air ducts from above decks, and each blower having a capacity of 10,200 cubic feet of air per minute, with an air pressure of one inch of water in the fire rooms.

AUXILIARY BOILERS. DATA.

	One boiler.		*Total both boilers.*
Diameter, feet and inches		10–1$\frac{3}{32}$	
Length, feet and inches		8–6	
Number of furnaces	2		4
Diameter furnaces, outside, inches		37	
Diameter furnaces, inside, inches		33	
Length grate, inches		70	
Tubes, number ordinary	158		316
number stay	58		116
outside diameter, inches		2$\frac{1}{2}$	
center to center, horizontally, inches		3$\frac{3}{4}$	
center to center, vertically, inches		3$\frac{1}{2}$	
total number	216		432
Heating surface, square feet	976.32		1,952.64
Grate surface, square feet	32.		64.
Ratio G. S. to H. S		1 to 30.51	

Auxiliary Condensers.—There are two auxiliary condensers (Wheeler Condenser and Engineering Co., New York), each with an attached combined air and circulating pump $\frac{8 \times 10 \times 10}{12}$ of Knowles pattern. The cooling surface of each condenser is 680 square feet. They are located in the forward engine rooms, secured to the middle fore-and-aft bulkhead, at the level of the middle of the main cylinders.

Refrigerating Plant.—This is similar to that described for the *Columbia*. An Allen's dense air ice machine (1 ton per day normal capacity) is connected to a large cold storage room and to the ship's scuttle butts and freezing tanks.

U. S. S. *MINNEAPOLIS*, MAY 10, 1894.

FIVE-HOUR TRIAL OF ALLEN DENSE AIR ICE MACHINE.

Time.	Revs.	H. P. air.	L. P. air.	Temp. meat house.	Lbs. of ice.	Temp. scuttle butt.	Gallons water drawn off.	Time of drawing off water.
9·45 A. M.....	144	268	68	22	...	38	..	.....
10 15	147	268	68	21	...	39	30	9·45—10·15
10·45	136	263	67	21	17	39	...	.....
11·15	128	250	65	19	...	39	...	.....
11·45	147	267	67	18	17	40	21	11·15—11·45
12·15 P. M.....	139	263	67	16	51	39	...	.....
12·45	136	268	68	16	17	38	21	12·15—12·45
1·15	133	257	65	16	...	39	30	12·45— 1·15
1·45	128	259	68	16	...	40	15	1·15— 1·45
2·15	134	265	69	17	...	40	...	.....
2·45	134	255	64	16	46	44	39	2·15— 2·45
Total	...	...	...	...	148	...	156	.....
Avg. per hour..	136.2	261.5	66.8	17.6	29.6	39.7	31.2	.....
Rate per day...	...	...	...	17.6	710.4	...	748.8	.....
Contract per day.....	...	...	...	about 32	200	nearly 40	300	.....

Machine was started at 9 P. M., May 9th, on brine tank, cooling chloride calcium, and on everything at 11·45 P. M.

Distilling Apparatus.—There is a double distilling plant (Baird's) with a normal combined output of 10,000 gallons of potable water a day, in temperate climates. The two evaporators are vertical cylinders with horizontal nests of U tubes, and the two distillers are of the three coil type. The evaporators can be connected with the condensers so as to be used to make up feed water deficiencies, but the domestic consumption of fresh water on a modern man-of-war and the usual falling off of evaporator and distiller output in practice, and in hot climates, makes this assistance to the boilers very uncertain.

Workshop.—There is a well-fitted up workshop above the protective deck, just over the port after end of center engine room. It contains all the necessary tools for such general machinery repair work as is likely to be required at sea.

Electric Plant.—This differs from the *Columbia* in division more than total capacity, there being here three 24-kilowatt marine sets (General Electric Co., Schenectady, N. Y.,) against the two 32-kilowatt sets on that ship. Each dynamo has an output of 300 amperes at 80 volts, with an engine speed of 400 revolutions. The engines are "direct coupled" with their dynamos, and have two simple cylinders 10½ by 5.

The following (16-candle power) lamps are installed or provided for:

Battle lanterns,	38	single.
Deck lanterns,	28	"
Portable hand lamps,	104	"
Ceiling ring lamps,	84	"
Bulkhead lights,	72	"
Coal bunker lights,	50	"
Steam tight globes,	51	"
Desk lights,	37	"
Magazine lanterns,	9	double.
Ring lanterns,	2	"
Signal lights,	9	"
Top lights,	1	"
Truck lights,	2	"

Masthead and towing lights, . .	2 double.
Cargo reflectors, ...	4 quadruple.
	493

There are two search lights, one of 24 inches diameter and 75 amperes, and one of 30 inches diameter and 100 amperes.

In the main engine and main boiler rooms there are distributed the following of the above named lights:

56	portable hand lamps.
11	bulkhead lights.
14	steam tight globes.
1	ceiling ring.
20	coal bunker lamps.
16	deck lanterns.
118	

These rooms are also fitted with a complete set of improved reflector bulkhead lamps for burning heavy oil, and it is a remote contingency that will place this department in darkness.

Drainage System.—The drainage system is as simple and well devised as practicable. Two large drain pipes run along the middle of the bilge throughout the machinery compartments, each having branches (with valves worked from the upper decks) leading to a cistern in each compartment. The larger (main drain, 12 inches diameter) is operated by the wrecking pump and one main circulating pump in each engine room, while the smaller pipe (auxiliary drain, 7 inches diameter) is connected, through proper manifolds, to the suction of ten of the auxiliary steam pumps. These two drains are also connected with each other by a pipe and valve. The double bottom compartments are pumped out, through manifolds, by separate branches from the auxiliary pumps.

By placing the manifold valve boxes in conspicuous and accessible positions and having each valve clearly labeled with its connection, an apparently intricate maze of piping is made readily manageable by men of ordinary intelligence, and without over-long apprenticeship.

An excellent system of electrical and voice-tube communication is established between the important stations in the ship, and the usual modern engine telegraphs, tell tales, and speed and helm indicators are properly installed.

The ship is ventilated by four large Sturtevant blowers (60 inch), and there is a separate ventilating fan for each engine room and for the distiller room.

There are eight ash hoisting engines, four ammunition hoists, and three winches, all of the well-known Williamson Bros. make. This firm also built the steering engine (13 by 10), and all their machinery is characterized by excellence of workmanship and efficient performance.

The steam capstan or windlass was built by the American Windlass Co., and has a double cylinder engine, 12 by 14 inches.

The steam launch machinery is of Bureau design, with the improved Towne boiler.

Coal Bunkers.—There are 60 separate bunkers with an estimated capacity of 1,518 tons.

The performance data and indicator cards are here presented for the contract trial only. The data for coal consumption trials was given in the last number of the JOURNAL, and in view of the fact that those results are merely approximations, there is no necessity for tabulating them in a more expanded form at this time.

CONTRACT TRIAL DATA.

Draught of water, beginning of trial, forward, feet and inches	22–1
aft, feet and inches	23–4
end of trial, forward, feet and inches	21–4
aft, feet and inches	23–3
mean, forward, feet and inches	21–8½
aft, feet and inches	23–3½
average on trial, feet and inches	22–6
Displacement (mean) tons	7,387.
Area immersed midship section	1,125.
Wetted surface, square feet	27,660.
Mean speed, knots per hour	23.073
I.H.P. main engines only, A	20,366.23
main engines, air and circulating pumps, B	20,453.40
all machinery in use	20,862.30

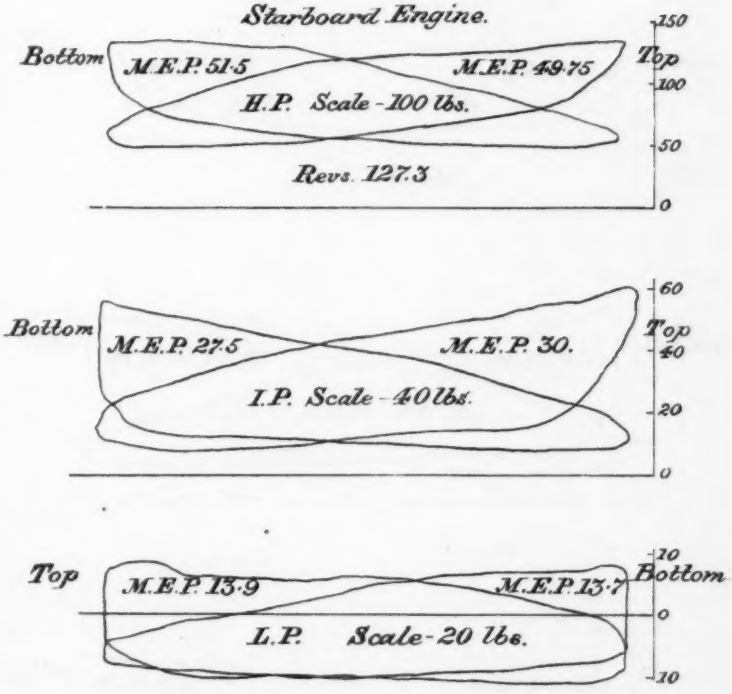
Speed^3 × area immersed midship section ÷ I.H.P. (B)	675.65
Speed^3 × displacement$^{\frac{2}{3}}$ ÷ I.H.P. (B)	227.81
I.H.P. per 100 square feet wetted surface. (B)	73.95
Screw propellers, number	3
number blades each	3
diameter, feet and inches, center	14–6
wing	15
Helicoidal area, center, square feet	53.28
starboard, square feet	53.7
port, square feet	53.7
total, square feet	160.68
Pitch on trial, center screw, feet	21.6
wing screws, feet	22.
mean pitch of three screws, feet	21.86

SYNOPSIS OF STEAM LOG.

		Center.	*Starboard.*	*Port.*
Slip of screws, per cent		17.73	19.44	20.15
Revolutions main engines per minute		132.19	131.95	133.1
Revolutions main engines, mean			132.4	
Piston speed, feet per minute		925.33	923.65	931.7
Steam pressure (mean) at engines		148.1	150.7	149.
Steam pressure first receiver, absolute		72.5	74.8	72.9
Steam pressure second receiver, absolute		24.6	26.3	27 4
Vacuum in condenser, inches		25.31	25.11	24.76
Throttle-valve opening			Wide.	
Steam cut-off in fraction of stroke from beginning,	H.P.	.62	.67	.66
	I.P.	.71	.72	.71
	L.P.	.70	.70	.69
Temperatures in degrees Fahrenheit,	Engine rooms		88.1	
	Injection	61.	61.	61.
	Discharge	117.7	125.3	125.3
	Feed at tank	122.8	124.7	139.8
Air pressure in fire rooms, in inches of water			1.	
Mean effective pressures,	H.P.	51.91	49.32	46.39
	I.P.	31.20	34.53	28.52
	L.P.	15.04	13.33	13.90
Aggregate equivalent pressure referred to L.P. piston		38.87	35.54	35.09
Revolutions or double strokes per minute,	Main air pumps	13.7	15.	18.6
	Main circulating pumps	159.4	240.5	168.8
	Four main feed pumps, average		30.7	
	Sixteen forced-draft blowers, average		584.	
	Three fire and bilge pumps, average		47.2	

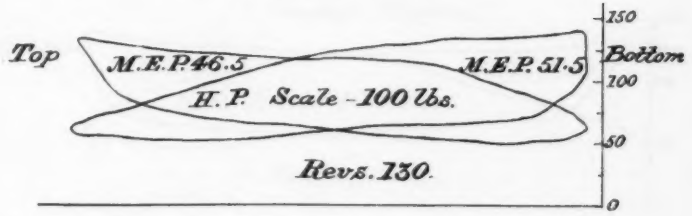
		Center.	*Starboard.*	*Port.*
I.H.P.	H.P. cylinder	1,978.92	1,876.36	1,779 93
	I.P. cylinder	2,370.87	2,239.48	2,181.18
	L.P. cylinder	2,869.03	2,470.88	2,599.58
	Collective, each main engine	7,218.82	6,586 72	6,560.69
	Collective, all three main engines		20,366.23	
	Main air pumps	* 8.39	10.91	13.87
	Main circulating pumps	18.44	18.	17.56
	Four main boiler feed pumps		90.96	
	Sixteen forced draft blowers		263.04	
	Other auxiliaries		54.90	
	Collective, main engines, air and circ. pumps		20,453.40	
	Total all machinery in use		20,862.30	
Indicated thrust (main engines only) pounds		83,487.	74,852.	73,996.
Indicated thrust per square foot of developed blade area, pounds		1,566.9	1,393.89	1,379.52
Indicated thrust per square inch of thrust bearing		33.	29.6	29.28
Cubic feet swept per minute by L.P. piston, per horse power		5.89	6.45	6.53
Ratio of volume swept by L.P. piston to that of two air-pump buckets per minute		88.9 to 1	75.7 to 1	61.6 to 1
Square feet cooling surface, 3 main condensers			28,422.	
Square feet cooling surface, per I.H.P. main engines			1.39	
Heating surface in use			48,194.54	
Grate surface in use			1,456.2	
Square feet total H.S. per total I.H.P.			2.31	
I.H.P. per square foot grate surface, total			14.33	
I.H.P. per ton machinery (penalty weight)			10.64	

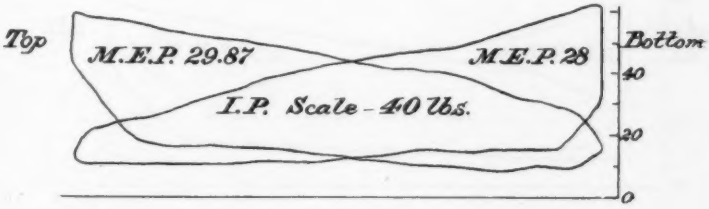
U.S.S. Minneapolis.

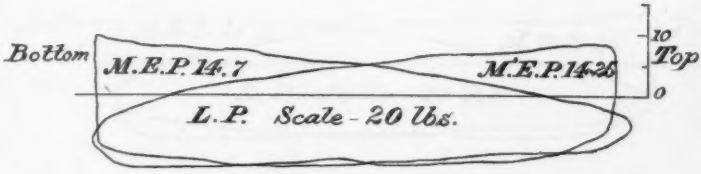


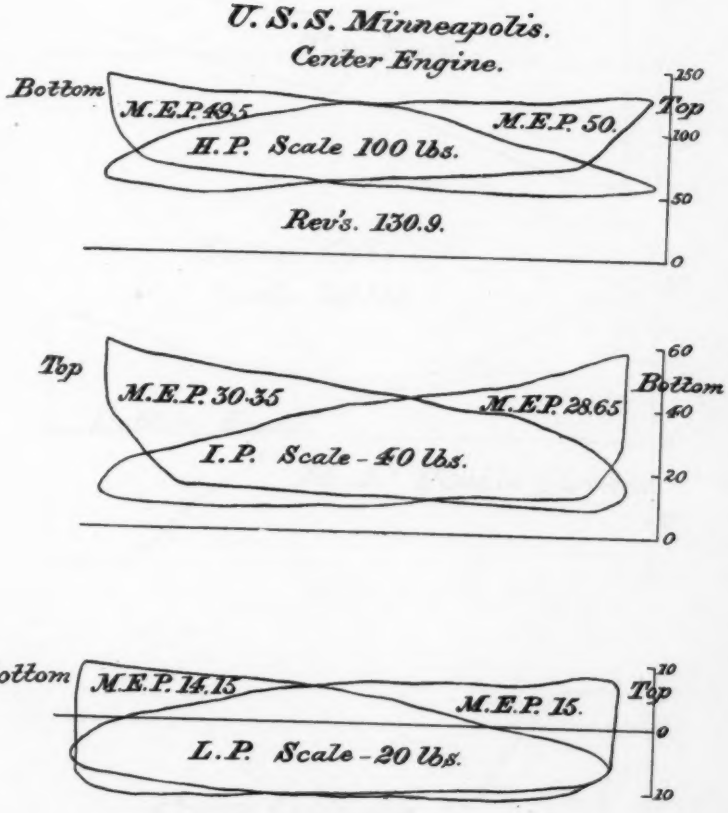
U. S. S. Minneapolis.

Port Engine.

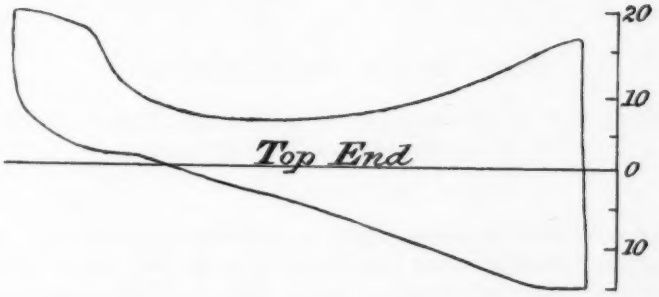




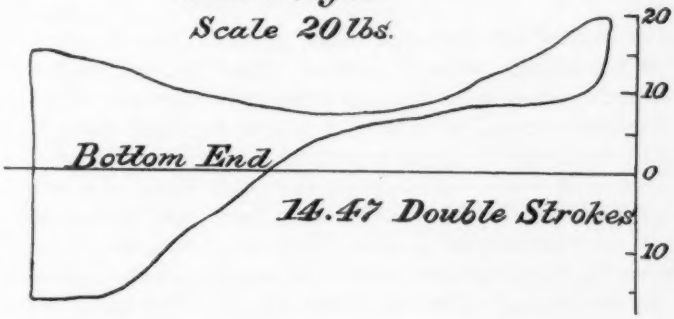


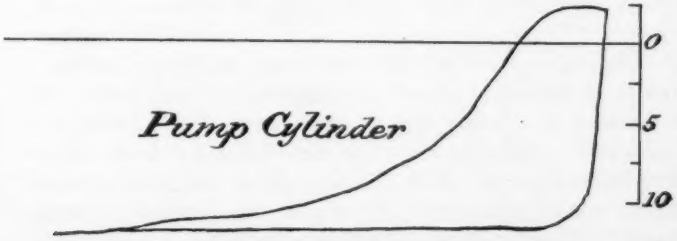

U. S. S. Minneapolis.
Center Engine.
Bottom
M.E.P. 49.5
M.E.P. 50.
Top
H.P. Scale 100 lbs.
Rev's. 130.9.
250
100
50
0
Top
M.E.P. 30.35
M.E.P. 28.65
Bottom
I.P. Scale - 40 lbs.
60
40
20
0
Bottom
M.E.P. 14.15
M.E.P. 15.
Top
L.P. Scale - 20 lbs.
10
0
10

Center Main Air Pump.



Steam Cyls.
Scale 20 lbs.





Scale 10 lbs.

WELDED STEEL STEAM PIPES.

By Warren E. Hill, Esq., Vice-President of The Continental Iron Works, Brooklyn, N. Y.

During the construction, at The Continental Iron Works, of the welded steel pipes for the United States protected cruisers *Columbia* and *Minneapolis*, it was suggested that a section of the largest size pipe be made and subjected to a bursting strain, in order to prove the value of both the longitudinal and circumferential weld.

Our contract for these steam pipes with the William Cramp & Sons Ship and Engine Building Company, the builders of the vessels and machinery, called for a full set of boiler connections of inside diameters varying from 10 to 20 inches, a thickness of $\frac{5}{16}$ to $\frac{3}{8}$ of an inch, and a maximum length of 16 feet, with flanges from $\frac{3}{4}$ to 1 inch thick after being faced. These pipes were to be made of plate steel, and were to comply with all the requirements called for in the specification of the material used in the boilers, and be subjected to a water test pressure of 400 pounds per square inch. As the bolt holes in the flanges were not to be drilled by us, the pipes were prepared for testing, by clamping blank flanges on each end, and not by putting the pipe between platens, held by long bolts, to form tight end joints, as the latter mode would have relieved the circumferential, or cross-welds, of all strains.

Before describing the construction of the experimental pipe, which was tested to destruction, it may be interesting to describe our practice in forming these flanged pipes, as it is unlike the system used in Great Britain and other countries. The plate to form the pipe, after being scarphed on the edges, is rolled to the diameter required and then welded, the length of the cylinder being about 8 inches shorter than the finished length of the pipe

over the flanges. Steel discs of the requisite diameter and thickness to form the flanges, after having a hole punched in their center, are flanged like a "flue head", with the cylindrical projection of the desired length, which, when scarphed in a lathe, is welded circumferentially to the cylindrical part of the pipe. Welded steam pipes, as used in European practice, are generally made of iron and have their flanges, which are of cast steel or welded angle iron, screwed or riveted on to the body of the pipe.

In making the experimental pipe we used $\frac{1}{4}$-inch plate, as we anticipated the difficulty of making rivets in the heads remain tight under such a pressure as would be required to burst a vessel of the same diameter and $\frac{3}{8}$ of an inch thick. This proved true in our experimental experience. The pipe was 20 inches inside diameter and 42 inches long over the flanges. The heads were formed of $\frac{1}{2}$-inch plate, domed about 6 inches, and secured to the pipe flanges, which were $\frac{3}{4}$ of an inch thick, by twenty-four $\frac{7}{8}$-inch rivets, the holes being slightly countersunk at the head and point of rivets. As the radius of the interior curve on the flange was one inch, the total area to strain the rivets was that of a diameter of 22 inches.

In the first experiment we obtained a gauge pressure of 1,000 pounds, when the packing of the pump plunger gave out and leaked more than we could gain by further pumping. We then released the pressure entirely, repacking the pump plunger, and again tried to burst the pipe, but could not obtain any pressure at all, as every rivet in the head leaked, which was not the case when under the 1,000 pounds pressure, showing that the rivets had been strained in the direction of their length, and that the cupping made a valve and seat, the caulking edge of the heads acting as a fulcrum to keep the rivets tight; and, upon the release of the pressure, the rivets did not return to their normal position and length, hence the great leakage and no pressure, and our experiment was ended for the day.

We then removed all the rivets, and drilled holes $1\frac{1}{16}$-inches diameter, making a considerable countersink on each side, and drove the rivets by machine. Upon putting the pressure up to

1,500 pounds to the inch, we had many pin hole leaks in the riveting, but by working the pumps very rapidly, we were enabled to overcome the loss of water, and finally succeeded in exploding the vessel with a pressure of 1,700 pounds to the square inch. It enlarged like a barrel, becoming over 24 inches in diameter at the middle of its length. The fracture occurred about 6 inches from the line of the longitudinal weld. This great pressure would give a strain of about 68,000 pounds on a square inch of section, and as that was more than we thought the tensile strength of material could be, we questioned the accuracy of the gauge, which we sent to the manufacturer to be carefully tested. They returned the gauge to us with a certificate that it indicated correct pressures.

Three test pieces were then cut from the exploded vessel, two of them being cut across the welded seam, leaving the welded part in the middle of the length, and the other from the unwelded part of the steel.

A copy of the test made by the Fairbanks testing machine in New York City is appended. It shows a maximum tensile strength for the two having the weld of 58,230 pounds and 62,500 pounds, respectively, and for the unwelded piece 61,470 pounds. The fracture in all the pieces occurred near the ends, several inches from the weld.

How to reconcile the discrepancy between the strength shown by the testing machine and that indicated from the pressure gauge, I leave to others to determine; but the satisfactory part of the whole operation, and that which proves the value of the welded seam, is that the pieces cut from the weld stood as much pull as the piece cut from the same vessel in which there was no weld.

In the accompanying illustrations, No. 1 shows the vessel before the application of pressure. Nos. 2 and 3 the same after destruction, showing the distortion.

No. 4. Exploded vessel with the lines of the longitudinal and circumferential welds indicated, and showing position of the test pieces.

No. 5. A sectional drawing of the vessel, the dotted lines showing its original size and shape, and the full section lines its distorted shape, the rupture, and its position relative to the longitudinal weld.

The construction of this experimental pipe was carried out under the inspection of an officer of the Engineer corps of the Navy, who was the inspector of the completed pipes for the *Columbia* and the *Minneapolis*, as well as of their corrugated furnaces, and the tests which have been described were made in the presence of this officer, or of others who have been on duty at the Continental Iron Works. The last test was witnessed by Chief Engineer B. F. Wood, U. S. N., who can vouch for the accuracy of the pressure recorded by the gauge at the time the pipe burst.

[At first sight there appears to be a great discrepancy between the tensile strength of the metal, as indicated by the testing machine, and that given from the gauge pressure, leading to the conclusion that the gauge pressure is incorrect. A careful examination of the outline of the ruptured vessel, No. 5, will, however, show that the stress on the metal at the time of rupture was much greater than would be obtained from a consideration of the original diameter and thickness of the metal.

The outside circumference from edge to edge of the rupture, at about the middle of its length, is $75\frac{11}{16}$ inches, corresponding to an outside diameter of 24.095 inches. The thickness of the metal at this point was .206 inches, making the internal diameter at the time of rupture $24.095 - 2 \times .206 = 23.683$ inches. Using these figures for thickness and diameter, the stress on the metal when the vessel burst becomes:

$$f = \frac{1{,}700 \times 23.683}{2 \times .206} = 97{,}720 \text{ pounds.}$$

Test specimen No. 1 measured approximately .765 by .171 inch at point of fracture; or its area was .1308 square inch. The total stress on it at the time it broke was 14,150 pounds, and consequently the stress per square inch was

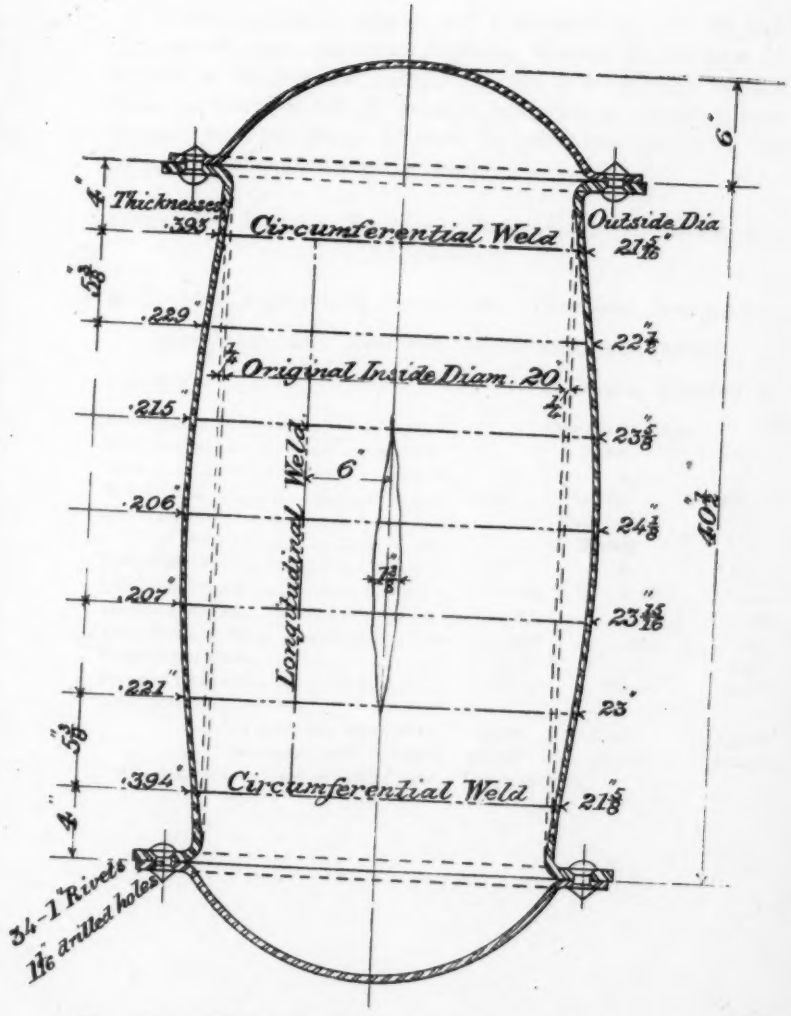
$$\frac{14{,}150}{.1308} = 108{,}200 \text{ pounds.}$$

No. 1.

No. 2.

No. 3.

No. 4.



Bursting Pressure 1700 lbs. per sq. in.

No. 5.

Similarly, specimens Nos. 2 and 3 measure .775 by .165 and .783 by .169 inch respectively, giving stresses at the time of fracture of 109,500 and 100,800 pounds, or an average for the three specimens of 106,167 pounds; a result near enough to that obtained from the gauge pressure to leave little doubt of the correctness of the latter.—EDITOR.]

FAIRBANK'S TESTING MACHINE—DEPARTMENT OF TESTS AND EXPERIMENTS.

N. O. Olson, Engineer, 84 Thomas Street, New York, June 9, 1894.

REPORT OF TESTS MADE FOR CONTINENTAL IRON WORKS.

(Copy) N. O. OLSON, *Engineer.*

Source	Carnegie & Phipps.		
Material	Steel.		
Mark	1	2	3
Test No.	12,279	12,280	12,281
Shape, original	Boiler plate.		
of test piece			
Length, inches	8	8	8
Width, inches	1.015	1.008	1.010
Thickness, inches	.239	.222	.215
Area, square inches	.243	.224	.217
Final length, inches	9.50	9.28	9.28
Per cent. elongation	18.75	16.00	16.00
Stress, tensional, pounds:			
on specimen, maximum	14,150	14,000	13,340
per square inch, maximum	58,230	62,500	61,470
REMARKS.—Tests 1 and 2, welded joint.	Test 3, no weld.		

POTENTIAL AND ECONOMIC EFFICIENCY OF DAVIS' FOUNDRY COKE UNDER CONDITIONS OF ACTUAL SERVICE ON BOARD THE U. S. STEAMER *DOLPHIN*.

By Chief Engineer George W. Baird, U. S. Navy.

The purpose of the experiment herein recorded was to determine the potential and economic efficiency of coke, and its merits as to stowage, safety, convenience and cleanliness on board a vessel at sea.

The *Dolphin* is a single screw steel steamer, officially designated as a "dispatch vessel," and is of the following dimensions: Length between perpendiculars, 240 feet; breadth, 32 feet; mean draught, 14.25 feet; displacement, 1,485 tons. Her engine is of the vertical inverted cylinder, compound type, with two cylinders, driving a single screw. There are two large and two small boilers of the horizontal return tubular type, but the number of firemen allowed the vessel is barely sufficient for operating the two large ones, and therefore the latter only were used during this test.

The air and circulating pumps are operated by an independent engine, as is also the main feed pump and the pump which flushes the closets, the latter being in operation continuously. There is one blower and two exhaust fans, all of which deliver into the open fire rooms. The latter are run from nine o'clock in the evening until half past five in the morning, for the purpose of ventilating the sleeping apartments, but they do not sensibly increase the draft of the fires. The fire room blower was not used during this test.

The dynamo engine carries no other load than the dynamo. At sea it is run all night, from dark to daylight, but in port it is

stopped at midnight. A record is kept of its output, as well as of the steam pressure and revolutions.

The power required to operate these auxiliaries has been determined either from indicator diagrams, or from the condensed exhaust being trapped on former occasions and measured; and the power used during this experiment was calculated from the above, and is believed to be a fair approximation. That required to work the steering engine has been neglected, as its work is necessarily intermittent, and varies not only with the state of the sea, but also with the skill of the seaman who handles the steering wheel.

All of the indicator diagrams from the main engine cylinders were taken by the writer, who also made all the measurements and calculations, and who is alone responsible for their correctness.

The test was made during the voyage from Washington to New York. It commenced when the ship was fairly under way, and continued until the coke was all burned, a period of 27½ hours, and was made without interfering in any way with the regular service of the vessel. The number of the counter was recorded at the beginning and at the end; the height of the water in the boilers and the condition of the fires were noted at the beginning, and at the end were brought to the same condition.

The following analysis of the coke was furnished by Mr. Wm. M. Winks, who supplied the fuel:

Fixed carbon,	90.734
Volatile matter,	1.380
Ash,	6.520
Sulphur,	.147
Water,	1.200
Phosphorus,	.019
	100.000

Following are the principal dimensions of the boilers and machinery used during this test, and also the results:

BOILERS.

Number	2
Diameter, feet	11
Length, feet	18

Furnaces, total number in use	8
internal diameter, feet	3.33
length of grates, feet	6.75
Grate surface in each furnace, square feet	22.50
aggregate, square feet	180.
Tubes, aggregate number in both boilers	872.
external diameter, inches	2 75
thickness, B.W.G	12.
spacing, vertically, inches	3.75
spacing, laterally, inches	3.87
mean length, feet	6 33
Least distance between tubes and shell of boiler, inches	7.
Least distance between the nests of tubes, inches	10.
Aggregate water heating surface in both boilers, square feet	4.367.
Steam drum, diameter, feet	7 5
height, feet	8 5
number of flues through	7.
internal diameter of flues, inches	15.5
Aggregate area for draft:	
over the bridge walls of both boilers, square feet	38.2
through the tubes of both boilers, square feet	30.51
through and around the steam drum, square feet	46.2
through the chimney, square feet	41.
Volume of water contained in both boilers, cubic feet	671.
Volume of steam space in both boilers and in the steam drum, cubic feet	836.
Ratio of water heating surface to grate surface	24 3
grate surface to area over the bridge walls	4.75
grate surface to area through the tubes	5 9
grate surface to area through smoke-pipe	4 4
Smoke-pipe, height above grates, feet	56.83
Grate bars, width of top edge, inch	1.
width of air space between, inch	.63

ENGINE.

Number of steam cylinders	2
Diameter of the small cylinder, inches	42
piston rod, inches	7
tail rod, inches	4.34
Net area of the small cylinder, square inches	1,358.69
Space displacement of the piston of the small cylinder, per stroke, cubic feet	37 74
Clearance in steam passages, and between piston and cylinder head, at one end of the small cylinder, cubic feet	3.76
Ratio of piston displacement to clearance	10 04
Diameter of the large cylinder, inches	78.
piston rod, inches	7.

Diameter of the tail rod, inches	4.34
Net area of the large cylinder, square inches	4,751.62
Stroke of piston, feet	4.
Space displacement of the piston of the large cylinder per stroke, cubic feet	132.
Clearance in steam passages, and between piston and cylinder head, at one end of the large cylinder, cubic feet	8.77
Ratio of piston displacement to clearance in large cylinder	15.05
of large cylinder and its clearance to that of the small cylinder	3.39
Aggregate volume of the receiver, cubic feet	130.

AIR AND CIRCULATING PUMP.

This pump has a single horizontal steam cylinder which is connected directly to a single water end, which latter is the circulating pump; and by the intervention of a working beam it operates two single-acting, lifting air pumps.

Diameter of the steam cylinder, inches	22.
Length of stroke of piston, feet	2.
Diameter of the circulating pump cylinder, inches	26.
Stroke of the circulating pump piston, feet	2.
Diameter of the air pump cylinders, inches	24.5
Stroke of the pistons of the air pumps, feet	1.75

FEED PUMP.

Diameter of steam cylinder, inches	10.
Diameter of water cylinder, inches	6.
Stroke of piston, foot	1.

VENTILATING FANS.

Number of fans in operation	2.
Diameter of steam cylinders, inches	6.
Stroke of pistons, inches	6.

FLUSHING PUMP.

Diameter of steam cylinder, inches	5.5
Diameter of water cylinder, inches	5.
Stroke of piston, inches	8.

DYNAMO ENGINE.

Number of steam cylinders	2.
Diameter of cylinders, inches	8.5
Stroke of pistons, inches	6.
Intended number of revolutions per minute	400.

MANNER OF MAKING THE EXPERIMENT.

The tubes in the boilers were swept, furnaces cleaned and then primed with coke. The boilers were filled to "steaming level" with fresh water and steam raised with coke as the fuel, but the experiment was not held to commence until the ship was well under way. A number of tubs of coke had previously been weighed and averaged and a record kept of the number used, from which the weight was calculated. The ashes were weighed dry.

The main engine ran continuously during the test, the pressures, temperatures, revolutions, etc., were noted hourly, and an indicator diagram was taken hourly from each end of each cylinder of the main engines. The revolutions of the ventilating fans, and the strokes of the feed and flushing pumps were counted at intervals and averaged.

The sea was smooth; the direction of the wind was generally on the beam, and its average force 1.6; no sails were used.

The speed was copied from the ship's patent log record, wherever entered in the log book, and where omitted in that journal it was calculated from the revolutions of the screw, based on the record between Cape Charles light ship and Scotland light ship.

TOTAL QUANTITIES.

Duration of the experiment, hours	27 5
Geographical miles run	313.6
Revolutions of the main engines	91,470.
of the air and circulating pump	23,100.
Pounds of fuel consumed	60,928.
Pounds of refuse	4,407.
Pounds of combustible	56 521.
Per cent. of refuse in the fuel	7.23
Time dynamo engine was in operation, hours	10.58
Time ventilating fans were in operation, hours	8.

THE ENGINE.

Mean steam pressure in the boilers in pounds per square inch above the atmosphere	51.
Mean steam pressure at the engine in pounds per square inch above the atmosphere	48.4

Mean steam pressure in the receiver in pounds per square inch above zero	18.9
Fraction of the stroke of the small piston completed when the steam was cut off	.621
Fraction of the stroke of the large piston completed when the steam was cut off	.498
Number of times the steam was expanded	5.17
Opening of the throttle valve, in eighths	2.4
Mean number of revolutions per minute	55.436
Vacuum in the condenser in inches of mercury	23.50
Height of the barometer in inches of mercury	30.26
Temperatures in degrees Fahrenheit:	
Atmosphere	76.7
Injection (sea) water	77.6
Discharge water	93 5
Feed water	119.1
Fire rooms	116.3

INDICATED HORSE POWER DEVELOPED PER HOUR.

In the small cylinder	449.11
large cylinder	404.17
Aggregate of the main engine	853.28
By the air and circulating pump engine	22.4
feed pump engine	3.
flushing pump engine	1.
By both ventilating fan engines	3.
Chargeable to ventilating engines $\left(\frac{8}{27.5} \times 3\right)$	.87
By the dynamo engine	11.04
Chargeable to the dynamo engine $\left(\frac{10.58}{27.5} \times 11\ 04\right)$	4.25
Aggregate for all the machinery for the period of the experiment	884.80

SPEED.

Total distance in geographical miles	313.6
Mean speed in geographical miles per hour	11.4
Slip of the screw in per centum of its speed	14.6

RATE OF COMBUSTION PER HOUR.

Fuel consumed, pounds	2,215.
Combustible consumed, pounds	2,055.
Fuel consumed per square foot of grate, pounds	12.3
Combustible consumed per square foot of grate	11.41
Fraction of a pound of fuel consumed per square foot of heating surface	.507
combustible consumed per square foot of heating surface	.470

WEIGHT OF STEAM ACCOUNTED FOR PER HOUR.

Pounds present in the small cylinder at the end of the stroke of the piston, calculated from the pressure there	17,116.
Pounds present in the large cylinder at the end of the stroke of the piston, calculated from the pressure there	16,968.
Pounds to run the feed pump	120.
Pounds for the air and circulating pump engine	896.
Pounds for the ventilating engines	49.5
Pounds for the flushing pump	31.
Pounds for the dynamo engine	366.
Pounds used to run all the machinery	18,578.5

ECONOMY.

Pounds of water per indicated horse power, calculated from the pressure in the small cylinder	20 05
Pounds of water per indicated horse power, calculated from the pressure in the large cylinder	19.85
Pounds of water per hour to run the engine room auxiliaries	40.08
Pounds of water per hour to run the dynamo engine	86.
Pounds of water vaporized per pound of fuel	7.73
Pounds of water vaporized per pound of combustible	8.33
Pounds of water that would have been vaporized per pound of fuel had the feed water been delivered at 212°	8.43
Pounds of water that would have been vaporized per pound of combustible had the feed water been delivered at 212°	9 08
Pounds of fuel per indicated horse power per hour for the main engines	2.594
Pounds of fuel per indicated horse power per hour for the engine room auxiliaries	4.73
Pounds of fuel per I.H.P. per hour for the dynamo engine	11.20
Pounds of fuel per nautical mile	194.3
Pounds of combustible per nautical mile	180.3

The coke was of excellent quality; it ignited readily, and its incandescent bed upon the grates showed no gases in combustion, nor was there, at any time, any smoke visible issuing from the smoke-pipe. Small particles of cinder at times came from the smoke-pipe, but they were so completely consumed that they left no black trace on being crushed. It burned freely, yielding but little ash and no clinker; it was more laborious in firing with it than with coal, for it was so light that the firemen were unable to throw it to the back of the grates by one operation, but were obliged to feed the front of the furnace and poke it

back with a hoe. This process would, however, be less with larger furnaces, such as sometimes exist in land boilers.

The coke is free from elements which are likely to produce spontaneous combustion.

It weighed 28.34 pounds per cubic foot, in tubs, but from its rough surfaces and projecting points it does not stow as easily as coal; it requires 84.5 cubic feet of bunker per ton, when the ordinary stowing is done. When run through the deck scuttles into the bunkers, it assumed a conical shaped pile, the sides of which were much nearer the vertical than would be the sides of a coal pile under the same circumstances. It then required more labor to trim than would coal. When the bunkers were so nearly full that the trimmers were obliged to come out, they found it impossible to fill in and stow from the scuttles much more than gravity would take care of. This left considerable empty space up under the deck.

Loaded into a bunker, the coke occupies more space than double its weight of anthracite, and would, therefore, produce less than half the length of voyage.

During the experiment the fires were urged as much as possible with natural draft, so the rate of combustion herein recorded may be regarded as the maximum under the circumstances.

Owing to the greater difficulty in shoveling, and the greater bulk to be handled, as compared with coal, it was found necessary to employ additional coal passers to handle the coke.

To ascertain the angle of repose of the coke compared with "stove size" anthracite coal, I built a pyramid of each, having a base one square foot in area; the coke could be built 12.5 inches in height and the coal but 7 inches.

SUCTION DRAFT FOR BOILERS.

RECENT EXPERIENCE WITH CYLINDRICAL BOILERS AND THE "ELLIS AND EAVES" SUCTION DRAFT.

By Mr. F. Gross.

[Paper read before the Institute of Naval Architects.]

At the last summer meeting Mr. Ellis read a paper on "Some Experiments on the Combination of Induced Draft and Hot Air applied to Marine Boilers fitted with 'Serve' Tubes and Retarders."

So much special attention is being given to boilers for ships at the present time that it will, perhaps, interest the members to be informed of the experience which has been gained to date with this system applied to marine boilers on land and at sea.

The boilers which have been working longest with this combination are at the Atlas Works, Sheffield. Nos. 7 and 8 are now three years old; Nos. 9 and 10 are two years old; Nos. 11 to 16 have since been gradually added. These ten single-ended marine boilers, placed together in one shop, furnish part of the steam required by the works, and are consequently at work day and night, except on Sundays and holidays. Their ordinary work is to maintain a regular combustion due to 3 inches vacuum at the fan inlets, corresponding to a combustion of 35 pounds to 37 pounds per square foot of grate, which is uniformly 5 feet 8 inches long in all the boilers. For short periods, at certain intervals during the day, the quantity of steam required is appreciably greater than the regular quantity, when by increasing the number of fan revolutions, the rate of combustion is immediately raised to 40 pounds, 45 pounds, 50 pounds, or even 60 pounds per square foot of grate, and as promptly reduced when the demand for the extra steam has passed away. It will be evident that, unlike boilers with natural draft, the boiler is the

constant quantity, whilst the draft is varied largely according to the requirements for the time being.

For the purpose of obtaining data on suction draft, fans of different diameters and widths are used. Likewise some fans work one boiler only, and are placed above the boilers; others work two boilers, and are placed on the ground floor, sucking the gases downwards, and discharging them into short funnels which just clear the roof of the building. The success of boilers Nos. 7 and 8 led to the construction of Nos. 9 and 10, and the satisfactory experience with the four led to the subsequent six, partly for the sake of space, partly for economy and absence of smoke. The ten boilers, 10 feet 6 inches by 10 feet 6 inches, displace three to four times as many Lancashire boilers of about 28 feet by 6 feet 6 inches, whilst the evaporation per pound of South Yorkshire coal is 9 pounds actual from cold feed (or 12½ pounds from and at 212 degrees) when burning at 30 pounds per square foot of grate, or 8½ pounds actual from cold feed (or 10 pounds from and at 212 degrees) when burning at 45 pounds per square foot of grate, as against 6½ pounds actual from cold feed in the Lancashire boiler burning at 19 pounds per square foot of grate with a chimney 130 feet high. Very recent careful examination of the boilers show that the Purves flues, tube plates, and "Serve" tube ends in the oldest are as good as new; and it is worthy of special note that the feed water comes cold from the river, unfiltered, and that the draft is not shut off when the doors are opened for firing, slicing or raking. The dampers are used only when the fires are being cleaned (every six hours). The fans likewise continue to work satisfactorily, as anticipated, because the gases, when entering the fans, do not exceed 450 degrees at the highest rate of combustion, the air heated by the waste gases then entering the furnaces at 320 degrees. For these boilers, owing to the steam pressure being, as yet, unavoidably only 50 pounds per square inch, the fan engines are simple engines.

The International Company's steamship *Berlin* (better known under the old name of the Inman Company's *City of Berlin*,) was the first steamer fitted with the draft, as conveniently as the

position of the eight single-ended boilers facing the center longitudinal line of the ship permitted. The air-heating tubes had in this case to be placed across the front, instead of lengthwise, of the boilers, offering consequently more obstruction, with less effective heating surface, than when placed in the usual way. She has been working hard since March 1, 1893, with satisfactory results, and has burnt at an average rate of 26 pounds per square foot of grate, 5 feet 3 inches long.

The same owners adopted this draft for the two new steamers built in this country, and recently completed, viz., the steamship *Southwark*, by Messrs. Denny, and the steamship *Kensington*, by Messrs. J. and G. Thomson, Clydebank. They are twin-screw sister ships, 480 feet long by 57 feet wide by 40 feet deep. The main engines are quadruple-expansion, and designed to develop 7,000 indicated horse power at trial trip.

The *Southwark* has two double-ended main boilers, 15 feet $9\frac{3}{16}$ inches in mean diameter by 21 feet $8\frac{3}{4}$ inches long, and one single-ended, 15 feet $9\frac{3}{16}$ inches in mean diameter by 11 feet 1 inch long. Each of the five boiler ends has four Purves furnaces, 3 feet 4 inches in inside diameter, grate bars 5 feet 9 inches long; total grate surface, 383 square feet; total heat-distributing surface inside the boilers, 12,285 square feet; working pressure, 200 pounds. Each boiler end has one exhausting fan, 7 feet 6 inches in diameter, and separate single-acting engine by Messrs. Sturtevant, of Boston, United States, these engines being used freely in the International Company's steamers. The "Serve" tubes in the boilers are $3\frac{1}{4}$ inches in outside diameter. At the trial trip, with a displacement of 12,300 tons, she easily developed the expected power, and gave the mean speed of 16.3 knots. On her station she has been running four round voyages, Liverpool to Philadelphia, almost entirely with two double-ended boilers only at work, with an average combustion of $27\frac{1}{2}$ pounds, which will gradually be increased.

In the *Kensington* the boilers are slightly longer, the double-ended, 21 feet 7 inches, and the single-ended 11 feet 5 inches. The total heat-distributing surface inside the boilers is slightly less, viz., 11,672 square feet. The number and size of Purves

furnaces, the length of grate bars, and diameter of "Serve" tubes are the same as in the *Southwark*. At the trial trip, with a displacement of 12,400 tons, she gave a mean speed of 15.8 knots. She has run one voyage west so far.

Whilst the foregoing steamers are giving experience for the Atlantic service, two other large steamers are doing the same for the long voyages to and from Australia. Messrs. Turnbull, Martin & Co., London, in the Australian dead-meat trade, have this combination draft in their new sister ships, *Perthshire* and *Buteshire*, built by Messrs. Hawthorn, Leslie and Co., Limited, Newcastle. These ships are 435 feet long over all, 54 feet wide and 32 feet deep. Displacement when fully loaded, 12,000 tons. For the power of 3,000 indicated horse power in each ship there are two single-ended boilers, 15 feet 6 inches in diameter by 12 feet long, each with three Purves furnaces, 3 feet 9 inches in inside diameter, and grate bars 5 feet 9 inches long. Total grate surface in each ship, 127 square feet; heat-distributing surface within the boilers, 4,770 square feet in each ship; working pressure, 160 pounds. The fans and triple-expansion fan engines are of Messrs. W. H. Allen and Co.'s make. Each ship has completed one round voyage to Australia and back. On the outward voyages, with an average indicated horse power of main engines of 2,450 to 2,500, the coal consumption averages about 26 pounds per square foot of grate. On the home voyage, requiring considerable extra steam for the large refrigerating machinery, the *Perthshire* averaged a combustion of 31½ pounds over 59 consecutive days, and the *Buteshire* 27½ pounds per square foot of grate over 56 consecutive days. The coal consumption of Newcastle small coal on the outward voyages averages 1.345 pounds per indicated horse power of main engines. This includes the power required by the fan engines. With South Wales coal the consumption of main engines will, therefore, be under 1.3 pounds per indicated horse power, after finding the power for the fan engines. Although the boilers of the *Perthshire* had been continually under steam for seventy-five days, being worked for fifty-nine days at this, for Australian voyages, unprecedented rate of combustion, the furnaces, tube plates, tube

ends and the fans were found in good order on arrival in London. These owners are fitting the draft arrangement to a third sister ship, the steamship *Banffshire*, now building by Messrs. Hawthorn, Leslie and Co.

Briefly summarized, the experience to date may be considered to have established a rate of combustion on a grate 5 feet 9 inches long, of 30 pounds to 60 pounds in marine boilers on land, and of 26 pounds to 31½ pounds at sea, in the Atlantic and Australian services, without troubles to furnaces, tube plates, tube ends, fans and fan engines, accompanied by an appreciable economy compared with boilers of the same size with plain tubes working with natural draft at half the rate of combustion.

The main factor in the economy is, of course, the "Serve" tube in combination with the retarder, because the "Serve" tube has on an average at least 75 per cent. more heat-"absorbing" surface than the same diameter of plain tube. The result is that at the highest rates of combustion, and with 3¼ inches diameter tubes (permitting natural draft to be readily used), the gases, when they reach the smoke box, do not exceed 700 degrees. The heat-absorbing surface of the air-heating tubes completes the economy, the gases reaching the fans cooled down to 300 degrees to 400 degrees, having heated the air to from 200 degrees to 300 degrees, according to the rate of combustion and amount of absorbing surface.

Against closed stokehold forced draft, burning at the same rate of combustion with plain tubes, the weight of the boilers with this system will be greater, but there is a considerable net saving in weight for other than short cross-channel voyages through the economy in fuel, which is naturally greatest against closed stokehold cold air draft. At a combustion of 30 pounds per square foot of grate, this economy will be at least 15 per cent.

Against Mr. Howden's latest practice, the excess of weight is trifling, being practically only the extra weight of the ribs in the "Serve" tubes, and of the greater surface of the air-heating tubes, and those produce a distinct economy in fuel of at least 7½ per cent. In a number of steamers working with Mr. How-

PARTICULARS OF SHIPS AT WORK WITH TH

	S. S. *Berlin.*	S. S. *Sa*
Length of ship	488 ft. 6 in.	48
Width of ship	44 ft. 0 in.	5
Depth of ship	36 ft. 9 in	4
Displacement at trial trip	.....	12,30
Number of boilers	8 S. E.	2 S. E. a
Size of boilers	13 feet 2½ in. mean diameter × 11 ft. 4½ in	15 ft. 9 3/16 i eter × 2 15 ft. 9 3/16 i eter × 1
Number of furnaces	24	20 P
Inside diameter of furnaces	38 in.	4(
Length of grate	5 ft. 3 in.	5 ft.
Total heat distributing surface in boilers reckoning outside surface of tubes	14,616 sq ft.	12,28
Total grate surface	396 sq. ft.	383
Working pressure	150 lbs.	20(
Number of fans	4	
Diameter of fans	7 ft. 6 in.	7 ft.
Mean speed developed at trial trip	.....	16.3
Average revolutions of fan engines	360	3
Number of voyages	17	
Average indicated horse power of voyages	5,566	4.4
Average coal consumption per indicated horse power	.....	...
Temp. of air before entering furnaces	260 deg.	271
Temperature of gases at fan inlet	441 deg.	393
Vacuum at fan inlet	3.5 in.	2.
Vacuum over fires	1 1 in.	.5

RK WITH THE "ELLIS AND EAVES" COMBINATION DRAFT.

	S. S. *Southwark.*	S. S. *Kensington.*	S. S. *Perthshire.*	S. S. *Buteshire*
	480 ft.	480 ft.	435 ft.	435 ft.
	57 ft.	57 ft.	54 ft.	54 ft.
	40 ft.	40 ft.	32 ft.	32 ft.
	12,300 tons.	12,400 tons.	7,500 tons.	.....
	2 S. E. and 1 D. E.	2 D. E. and 1 S. E.	2 S. E.	2 S. E.
	15 ft. 9 1/16 in. mean diameter × 21 ft. 8 3/4 in..... 15 ft. 9 1/16 in. mean diameter × 11 ft. 1 in..	15 ft. 9 in. mean diameter × 21 ft. 7 in..... 15 ft. 9 in. mean diameter × 11 ft. 5 in.....	15 ft. 6 in. mean diameter × 12 ft.	15 ft. 6 in. mean diameter × 12 ft.
	20 Purves.	20 Purves.	6 Purves.	6 Purves.
	40 in.	40 in.	45 in.	45 in.
	5 ft. 9 in.	5 ft. 9 in.	5 ft. 9 in.	5 ft. 9 in.
	12,285 sq. ft.	11,672 sq. ft.	4,770 sq. ft.	4,770 sq. ft.
	383 sq. ft.	383 sq. ft.	127 sq. ft.	127 sq. ft.
	200 lbs.	200 lbs.	160 lbs.	160 lbs.
	5	5	2	2
	7 ft. 6 in.	7 ft. 6 in.	8 ft.	8 ft.
	16.3 knots	15.8 knots.	11.75 knots.	.....
	317	.... .	320	.....
	4	.....	1	.....
	4.446	.....	2,450 outwards.	.....
	.....	.....	1.34 lb. Newcastle small.	.....
	271 deg.	.....	220 deg.	.....
	393 deg.	.....	310 deg.	.....
	2.9 in.	.....	1.75 in.	.....
	.8 in.	.....	.2 in.	.....

den's draft, the substitution of "Serve" tubes for plain tubes has at once given an economy of 10 per cent.; and it will be conceded that the horizontal air-heating tubes in the suction draft will be more effective than vertical tubes. Even with natural draft, with a funnel height of 75 feet or more, the "Serve" tube has proved, in a considerable number of vessels, that it gives an economy of 10 per cent. over plain tubes in the same boilers; and the special advantage of this suction draft combination is to give the same economy when burning at twice the rate in half the number of boilers, or to make the steam as economically as is now done with natural draft and plain tubes when burning at three times the rate in one-third the number of natural draft boilers.

Taking, therefore, boilers and coal together, this system requires in reality for moderate and long voyages the least weight of cylindrical boiler for a combustion of 25 pounds per square foot of grate and upwards; and as the action of the suction draft is to heat the boilers more uniformly the higher the rate of combustion (therefore the opposite of forced air-pressure draft), it is probable that we shall gradually see the boilers reduced more and more in size, and the rate of combustion at sea increased to 40 pounds, 50 pounds, and upwards per square foot of grate. Electric motors with small fans will assist in this direction, and the economy, safety and comfort of this system in working are strong recommendations for large passenger and cargo boats, whilst for warships the power to do away entirely with smoke, and even with funnels, should not be without importance.

The accompanying table gives the principal data for the five ships grouped together for handy reference.

The following abstract of the discussion on this Paper is from "Engineering":

Mr. F. Marshall was the first speaker who rose, on the President calling for a discussion. He said he had not had time to look into the figures in the paper in order to criticise them, but he had had experience of working with induced draft with two vessels he had in use, and they gave excellent results in fuel economy. When the paper was read at Cardiff, by Mr. Ellis, he had

not felt it open to him to speak definitely on the subject, but he could now say that induced draft was preferable to forced draft, as the latter would get itself into currents and eddies, and thus work holes in the fire. The more uniform working of the induced draft in the boilers spoken of led to no difficulties in this respect, neither the furnaces nor the tube ends giving trouble. The owners of the two vessels so fitted, on the experience gained on two voyages, ordered a third ship to be so fitted, a fact which was good practical testimony to the advantages. There were, of course, some drawbacks, and one was the difficulties that might arise through the number of machines that had to be kept constantly working; fans that ran 320 revolutions a minute required much looking after. In a vessel named the *Perthshire*, he had placed two fans, but he saw that in the larger vessels mentioned, five fans were used; every one knew that this meant a certain risk and much careful attention. Speaking on the subject generally, Mr. Marshall said that the advantages of getting the gases heated naturally suggested the use of smaller boilers, and thus securing a saving in weight. It must be remembered, however, that this saving would be partially counterbalanced by the weights of the fan and casings, and it was for owners to place one feature against the other. The fact, however, that the gases were so much reduced in temperature, before going into the funnel, was an important matter, the temperature of the gases in the *Perthshire* at the fan inlet being 310 degrees.

Sir Edward Harland wished to ask the author as to the effect of using heated air on the firebars. It was well known that at high rates of combustion, such as the auther quoted, the firebars were apt to suffer, and were only kept from destruction by the cold air preserving the lower parts at moderate temperature. As the air was so much heated before passing to the ashpit, would not the bars be likely to come down? With regard to the saving in fuel, the author quoted five voyages made with different ships, but he had only stated the coal consumption in terms of the indicated horse power in the case of one vessel, viz., the *Buteshire*, when the fuel burned was 1.345 pounds per indicated horse power for the main engines. Sir Edward would further like to

ask why the corresponding figures were not given for the other ships. The information would have been interesting, as the vessels were of different classes, and the comparison would, therefore, give data which would be of use. Referring generally to the principle, the speaker thought there would be very little saving of weight, taking into consideration the air passages, fans, etc. There was apparently no saving in coal, and though the boiler itself would be lighter, the air-heating apparatus, and other adjuncts special to the system, might counterbalance this advantage. Air was well known to be a bad conductor of heat, and would not as good a return be got if the air-tube surface used for heating the air to supply combustion was put into water-tube surface in the shape of a larger boiler? For his own part, he thought that he could get better results if water were used for absorbing heat rather than air. The arrangement was presumably intended more for the merchant service, as war vessels so often ran at reduced powers. He would ask, if a boiler burned a certain amount of coal in a given time, would the same saving be obtained if double the coal were burned? It was not a question in the merchant service how much coal could be burned in a given time in a boiler furnace, but rather what return was got from coal. The paper was, however, useful as opening the question whether induced or forced draft were preferable. It was difficult to see exactly where the difference came in. For his own part he did not think it very much mattered, if you wanted to remove a man from a certain position, whether you pulled him by the nose or gave him an impulse from behind. The effect of the fans working in hot gases was also a point to be considered.

Mr. J. I. Thornycroft said that the experiments were of great interest, as they showed that if a boiler can be made to stand burning coal at the rate quoted, there would be a saving of space in the ship. Owners wanted to save weight as well as space. He agreed, however, that air was not the most suitable material for extracting heat; but when suction draft was used the fans would work at less disadvantage if the gases were cooled, but he thought that by giving larger heating surface to the boiler the same result

might be attained. His experience of high rates of combustion was that a water ashpan was wanted, so that the air might be not only cooled but wetted, and he had met with cases where the water was actually carried to the bars, which were thus kept cool and not injured. Mr. Thornycroft also referred to what is undoubtedly a popular error in regard to forced draft—that it is very trying to stokers to work under. He said that he could see no objection to it at all; in fact, it made the stokehold a far cooler place than the engine room.

Mr. Fothergill agreed with previous speakers that it would be desirable to absorb the heat generated in the furnace by water rather than by air; that is to say, he would replace the air-heating arrangement of the author by additional heating surface in the boiler. He congratulated Mr. Gross on being able to burn 60 pounds of coal to the square foot of grate, but if more than 30 pounds was burned in a 3-feet diameter furnace, deep bars would be required and there would be little ashpit depth. Even then the fire would be too close to the furnace crown, so that there would be insufficient room for combustion. He thought that if 50 pounds of fuel were to be burned to the square foot of grate per hour, the water-tube boiler would offer advantages over the ordinary boiler and must come into use. Induced draft at high velocity may not be as hard on the furnace crown as forced draft, but the furnace bars would be as likely to be brought down, unless a water ashpan were used. He did not know which would be the worse calamity, the bars, or the furnace crown coming down. He would therefore say this, that either induced draft or forced draft was one of the requirements of the steamship of the future.

Mr. Gross, in replying to the discussion, said that a great many points were left out of his paper, as he did not wish to repeat what had been said by Mr. Ellis last year. In regard to firebars coming down, that undoubtedly would occur if they were arranged as in the ordinary case of marine furnaces, so that they tended downwards to the back. This had been one of the great difficulties that he had had to contend with in introducing the system. With the ordinary arrangement, grate bars rapidly

burned, often not lasting more than half an hour. At one time it seemed as if this objection would be fatal to the system, and many different devices were tried. The simplest was found to be the most effective. They raised the back end of the furnace until the bars were level, and at once there was a great improvement. This idea was carried a little further, the bars being carried two inches higher at the back end than at the front, and immediately all difficulties disappeared. No more conclusive proof of the truth of this statement could be desired than the fact that the *Perthshire* ran seventy-five days without difficuty. It had been questioned whether the high rates of combustion he had spoken of could be maintained, but by raising the bars two inches at the back, and using suction draft in place of forced draft, all difficulties would disappear, and 60 pounds of coal could be burned to the square foot of grate per hour with ease. The economy of the system he described had been questioned, but his paper had been written expressly to show that it insured economy, and if those who had spoken would carefully read and study what he had put before them, they would see that with no other system could the same satisfactory results be reached. It had been objected that the fans would not work well in the chimney gases on account of the heat, but at a temperature of 400 degrees to 500 degrees they had no difficulty in making these fans run satisfactorily any length of time. It was a question simply of the fan engine, and not of the fan itself, and if the engine did not break down, they could rely as absolutely on the draft as if a funnel were used alone. At the same time, he advised the owners of merchant vessels to keep their chimneys in place until they gained confidence in this new system, and they could then feel they could fall back on natural draft if necessary, as the tubes were of ample diameter. The number of fans used had been referred to. For his own part he preferred that each boiler should have a separate fan to itself, so as to make every unit self-contained; if one fan were not able to work, that boiler would be run with natural draft, and the other fans would be worked harder. In considering the weight question, no doubt more surface had to be apportioned to absorbing heat by air

than by water, but the air tubes in this case were very light and thin, and were not within measurable distance of the weight required for an equal area of boiler tubes.

Then, again, it was necessary for those who object to the additional weight of the air-heating apparatus, to take into consideration the weight of the fuel that was saved. He had made experiments in order to find out what were the relative advantages of heating the feed water, as against heating the feed air, and had found that there was no difference so far as economy was concerned, the water evaporated per pound of fuel being the same. He knew it was commonly thought that air was a very bad material for absorbing heat, but his experience had shown him that this was not so. In the apparatus referred to in his paper the air went through at a velocity of 2,000 feet per minute, and yet was reduced in temperature to the extent quoted. The result was that at the highest rates of combustion, with $3\frac{1}{4}$ inches diameter tubes in the boiler, the gases, when they reached the smoke box, did not exceed 700 degrees. The heat-absorbing surfaces of the air-heating tubes completed the economy; the gases reaching the fans cooled down to 300 to 400 degrees, having heated the air from 200 to 300 degrees, according to the rate of combustion and amount of absorbing surface. Mr. Fothergill had objected that perfect combustion could not be obtained in the low furnaces of an ordinary cylindrical boiler, but he (the speaker) would undertake to burn the fuel at any time without creating smoke.

Mr. Fothergill here pointed out that the absence of smoke by no means proved perfect combustion.

Mr. Gross said he would go further, and rely on the economy of fuel to prove perfect combustion. It had been asked why the coal economy of the other three ships was not given. He did not add the details to the particulars contained in the paper, as he only wished to put forward that which could actually be guaranteed, and on account of accidents which were not due in any way to the system he was describing—one being the breaking down of a cylinder and the other the failure of a propeller—it was not possible to ascertain the amount of fuel that was burned

in running under normal conditions. The difference between heat-collecting and heat-distributing surface in the Serve tube was to be noticed, and it had been questioned which should be taken as the true heating surface. Mr. Gross said, however, that there was no difficulty in transmitting to the water of the boiler all the heat that could be absorbed by the metal in the tube, so much greater was the power of transmission in the distributing than in the absorbing surface.

This paper, which was published in engineering papers generally, provoked considerable criticism, chiefly from Mr. Josiah McGregor, who, in the columns of "Engineering," held that the comparisons made between boilers fitted with Serve tubes and those with plain tubes were not fair, because the temperature of the escaping gases was not given; and that, with smaller plain tubes, the heating surface might be increased without reducing the draft area, and thus the plain-tube boiler be made to do as well as one with Serve tubes. As the replies by Mr. Gross give more information about the system than is contained in his paper, the greater portion of them is here reprinted.

The advantage of the Serve tube over the plain tube is due to its much greater heating surface, or rather "heated" surface, but instead of this being of "inferior quality," it is the reverse. A column of hot gases passing through a plain tube is soon comparatively chilled on the outside by contact with the relatively cool inside surface of the tube. The hotter portion of the gases near the center of the plain tube passes through the tube practically unused into the smoke box. The ribs of the Serve tube, on the other hand, purposely pierce this outer relatively cold zone of the gases, penetrate the column, and reach as near the center of the tube as is practicable in manufacture and as is desirable. If difficulties in manufacture did not prevent it, the ribs might be made so high that they would burn away on the edges, because these would be too far away from the water. The ribs, as made, are just below the limit of height at which this burning away would take place. There are Serve tubes in use which have now been working seven years without wasting the ribs.

We think it is now necessary to distinguish between the "*heat-*

absorbing" surface of the inside of the tube, and the "*distributing*" surface of the outside or water side of the tubes, instead of merely considering the outside surface as heating surface according to the custom hitherto. The Serve tube has the same "heat-distributing" surface as the plain tube of the same diameter, and does not need any more, but please note the very great difference in the amount of internal heat-"absorbing" surface. Taking ordinary diameters and thicknesses, and the absorbing surface of the plain tube as 100, the comparison is as follows:

Inches.	*Plain.*	*Serve.*
2½ O. D. × 11 G. . .	100	180
2¾ " × 10 G. . .	100	196
3 " × 9 G. . .	100	200
3¼ " × 9 G. . .	100	192
3½ " × 8 G. . .	100	195

Most vessels as yet use natural draft and plain tubes 3¼ inches or 3½ inches in diameter. Mr. McGregor suggests using a large number of smaller diameter tubes. This, of course, is not practicable for ordinary funnel heights, or it would be done now with plain tubes, but as it would mean that instead of 100 Serve tubes 3¼ inches outside diameter × 9 gauge, say 4¾ inches pitch, having 610 square inches of area for the gases, you would require 576 plain 1¼ inches outside diameter × 11 gauge, say 1⅞ inches pitch, to obtain with the same size of tube plate the same amount of (but we say less effective) absorbing surface, but only 452 square inches area for the gases, the question of draft at once makes the alternative possible, because the draft, consequently the rate of combustion and evaporation, would be seriously reduced. In the same manner for artificial draft, instead of 100 Serve tubes, 2½ inches outside diameter by 11 gauge, pitch 3¾ inches, with 350 square inches area for gases, 552 plain tubes, 1 inch outside diameter by 11 gauge, pitch 1½ inches, would be necessary for the same size tube plates, and this again would be found unworkable, the area for the gases being only 243 square inches. Instead of greatly increasing the existing fan power, which would be necessary when reducing so seriously the diameter of the tubes,

we recommend, for even high rates of artificial draft, that the diameter of the Serve tubes used be 3¼ inches, as with natural draft, which makes the work easier for the fans.

So far nothing has been said about retarders in plain and Serve tubes. It is now generally admitted by marine engineers who have tried them, that when the rate of draft is sufficient to admit of their use, thin flat strips of steel or iron twisted into spiral form, known generally as "Howden's" retarders, lying loosely in the plain tubes, produce economy of fuel or extra steam. This is due to the breaking up of the solid column of gases, and bringing more heat into contact with the absorbing surface, even of plain tubes, than would be the case without the retarders. The ribs of the Serve tube forming a much larger absorbing surface, and being an integral part of the tube itself, naturally absorb and conduct more heat to the surface than the retarder can in a plain tube; but the retarder itself can, and is, still more conveniently used in the center of the Serve tube, where it forces the gases into the spaces between the ribs, and consequently into contact with the heat-absorbing surface specially provided. Retarders could, of course, not be used in the plain tubes of the very small diameter necessary, as mentioned above, to obtain the same amount of absorbing surface with a given size of tube plate.

It follows from the above that "with a given rate of draft and a given size of boiler," the one with the Serve tube is far ahead of the one with the plain tube for effective heat-absorbing surface (no matter what the proportion of heat-distributing surface to grate surface may be), and the effect is shown by a marked reduction in the temperature of the gases in the smoke box. Of course, the amount of this reduction of the heat in the smoke box varies considerably between boilers working with natural draft due to a 75-foot funnel, say ⅜ inch to ½ inch vacuum, and the same boilers with fan-suction draft equal to 6 inches vacuum (which range can be seen at any time at our works), because, naturally, the higher the rate of draft the greater the advantage of the Serve tube over the plain one, with the same boiler. We have carefully avoided stating that a foot of Serve tube is worth a certain greater length of plain tube, because the

relation varies according to the rate and kind of draft, the length and diameter of the tube, without mentioning the variations in the coal. When our suction draft is used, the Serve tube, owing to the absence of smoke and soot, is, by reason of the clean surfaces, working under much better conditions than the plain tube does generally.

Having incurred the very considerable trouble and expense of studying these matters fully for the large range of draft named, and with and without retarders, we concluded that the best practical, if somewhat unusual, way of utilizing the information, is to inquire from the owners and engineers the conditions under which they propose to use the Serve tubes, to tell them frankly when the conditions are not suitable, and to give them a substantial guarantee for the first trial when they are suitable. As we supposed, this guarantee is readily accepted, and in fixing it, it is for us to make reasonable allowance for the many contingencies. Most people will agree that this is preferable to a table of laboratory equivalents, which would be misleading, because it would not have the liberal margin for contingencies which is necessary for usual sea practice.

It surely is evident that the value of the Serve tube lies in dealing with what would otherwise be *waste gases*, *i. e.*, the *residue of heat* passing out of plain tubes into the smoke box. Instead of 10 per cent. economy (or more, according to circumstances) being an insignificant gain, it is therefore quite the reverse. There are plenty of instances of 15 per cent. economy, and this, I believe, is equal to the average advantage obtained from tripling compound engines, involving new high-pressure boilers, therefore much more expense, and laying up the ship for a considerable period.

It is clear Mr. McGregor does not realize that so large an increase in absorbing surface is required as is the case to get 10 to 15 per cent. better results from the residue of heat, and that you can only get this great increase in absorbing surface with plain tubes by making your boiler much larger, if you retain your draft, or if you try to do it in the same size of boiler, by losing your draft and therefore your efficiency.

I do not withdraw the original statement that the absorbing surface of the Serve tube is of better quality than that of the plain tube, because, as already explained, the ribs penetrate into the column of hot gases, instead of being merely in contact with the cooled outside surface of the column.

The test made by the Mechanical Engineers with the S. S. *Iona* is well known. She had two boilers 13 feet 3 inches in diameter by 10 feet; grate area, 42 square feet; plain tubes, 3 inches in diameter; a total heating surface of 75.2 square feet to 1 square foot of grate, and at the trial burnt 22.4 pounds per square foot of grate 3 feet long. The late Dr. Kirk, with his assistant, made a trial with our No. 7 boiler, fitted with our suction draft complete (3¼-inch Serve tubes with retarders, air heated by waste gases), total heat distributing surface in boiler 28.4 square feet to 1 square foot of grate, which is 5 feet 8 inches long and 32 square feet area, the heating surface in the air-heating boxes for the residue of heat practically the same. We hold Dr. Kirk's report that this boiler, burning at *twice* the rate of combustion per square foot of grate, was as economical as the very economical boilers of the *Iona*. Her boilers have an almost unprecedented ratio of heating surface to grate surface. Even if, for the sake of argument, we add all our distributing surface inside and outside the boiler together, we only equal, say, 56 to 1, against the *Iona* 75.2 to 1 Her plain tubes are 3 inches outside diameter, our Serve tubes 3¼ inches. Still, the considerable loss which would naturally result from burning at double the rate in our boiler (= 45 pounds per square foot of grate), is recovered by our greater and better absorbing surface in the boiler, and subsequently by the air-heating tubes. We finish with even less temperature in the funnel than the *Iona*, which is the whole gist of the matter, as I have said before.

Your correspondent asks, What is our guarantee? When fitting the Serve tubes only (*i. e.*, not our suction draft complete), under guarantee, we naturally prefer to do so in a sister ship which is in all other respects identical with the ship with plain tubes already running or being built at the same time. Many of the latest cargo steamers are sufficiently large to require a

funnel 75 feet high from boiler grate for natural draft. With this funnel height, and, of course, with greater artificial draft, we are able to guarantee that the tubes will offer no difficulty in use by choking with soot or dirt, and at the same time that the ship with the Serve tubes will produce the same amount of steam as the sister ship with plain tubes, but will do this with at least 10 per cent. less coal. When there is no sister ship handy for comparison, we have agreed either on a definite consumption per average indicated horse-power, or on a definite daily total consumption. In other cases the tubes have been cut out of old boilers and replaced by Serve tubes with a similar guarantee. When the original funnel height has not been 75 feet in old steamers, it has been increased to 75 feet, and if the advantage of the Serve tube was not required as extra steam with the same amount of fuel, the length of grate has been reduced, and correspondingly less fuel burnt. In France, one line of steamers has gradually adopted the tube for the whole of its nine steamers. The French Admiralty use no other tube in their ordinary marine boilers, and even in the lower rows of their water-tube boilers. One of the most famous English lines has already favored us with the orders for retubing seven of their steamers, as the result of their own trial under guarantee. Our guarantees have not been imaginary ones. If the tubes had given trouble in use, we would have had to cut them out and bear the cost of replacing them with plain tubes. If they had not given the advantage, ascertained over a period of six to twelve months from trial trip, we should not have been paid the proper price for them.

Whilst these guarantees are being fulfilled all round, we have advanced a step further, and are able to obtain this saving with a smaller number of boilers by means of our complete suction draft arrangement.

REPAIRING A BROKEN VALVE CHEST ON THE *CONCORD.*

By Passed Assistant Engineer Harold P. Norton, U. S. Navy.

The *Concord* has twin-screw horizontal triple-expansion engines fitted with Marshall valve gear, and a complete description of the machinery will be found on page 89 of Volume III of the Journal, in the report of her official trial.

On the passage out to Hong Kong, the *Concord* made a stop of six days at the Island of Rong Sam Lem, in the Gulf of Siam, and advantage was taken of what little time the engineer's force was not on shore at rifle practice to overhaul the machinery, but very little was accomplished. On preparing for sea, fires were started in all the boilers (four) for the first time during the passage, and orders given by the commanding officer to run at full speed with natural draft.

The run to Saigon was a short one, about 24 hours, and the indicator cards taken from the port intermediate cylinder showed that something was radically wrong with the distribution of the steam to the outboard end of that cylinder. Although the engine was running very smoothly and regularly, it was thought that the rings, or some portion of the valve had carried away.

During the stay at Saigon this valve was examined and the outboard rings found to be very loose, so much so that it was thought that the leakage from the steam to the exhaust side of the valve would cause the irregularity shown on the cards. The valve was thoroughly overhauled and replaced.

The run to Hong Kong was made under the same conditions (four boilers), and the first set of cards showed that the trouble had not been remedied, and subsequent cards that it was increas-

ing, and that the leak was too much to be caused by a broken ring in the valve.

A copy of one set of indicator cards taken from the port intermediate engine when in its normal condition and running at ordinary speed is shown at "*A*", figure 4, and a set from the same cylinder taken during the passage between Saigon and Hong Kong at "*B*", figure 4.

During the stay at Hong Kong this chest and valve were thoroughly examined in search of the trouble, the valve being drawn, but everything in the valve chest seemed to be the same as when examined in Saigon. On removing the cylinder head and placing a candle up the steam passage leading from the outboard end of the cylinder to the valve chest, a break was discovered in the wall separating the live from the exhaust steam.

The valve chest lining at the outboard end was now withdrawn, and the extent of the break was plainly seen, as shown in Figure 1. The pieces marked *A* and *B* were entirely carried away, making a communicating opening, of their area, and the crack extending through the seating for the valve chest lining shown at *T*. The piece marked "*C*" was partly carried away and the crack extended close to the valve chest casing, entirely around the wall, or diaphragm, separating the live and exhaust steam passages, and passing through the rib, as shown at *G. O.*, figure 2, and to the center, as shown at *R* and *S*, figure 1. There was a core anchor or chaplet, as shown at *V*, figure 1.

The break was so extensive that it was decided that the best way to repair it would be to remove the broken diaphragm and fit a new one. The shape of the piece that was removed is shown in figure 3, and the extent of the cracks leading toward the centers at *R*, *S* and *T*. The thickness of the diaphragm at different points is also shown on figure 3, and it will be seen that the diaphragm was thicker at the bottom than at the top, while the ring forming the seat for the valve-chest lining is much thicker at the top than at the bottom, showing that the core must have moved when the casting was made.

The new diaphragm was made of composition, in five pieces, with lap joints (see figure 5), and to avoid the long and tedious

operation of chipping, in the confined space of the valve chest, the edge of the broken diaphragm down to a smooth surface, the new one was made with an offset so that it seated on the smooth valve chest casing. The piece marked *A* was the last one fitted, it being made with a slight taper in both directions, so that it acted as a wedge when drawn into place by the bolts in the diaphragm, and also by the bolts in the valve-chest casing. The I.P. cylinder lining was withdrawn so as to properly fit the flange bolts of the diaphragm. All the bolts in the flanges were through bolts, those through the cylinder casing having conical heads, and countersunk, as shown at *E*, figure 5, and those through the valve chest casing hexagonal heads, as shown at *F*, figure 5.

Three tie rods were fitted, as shown in figures 5 and 6, securing the new diaphragm to the solid one on each side of it. All joints were made with very stiff red lead putty, and the bolts set up as hard as possible.

After the new diaphragm was in place, it was bored out concentric with the others and the valve chest lining replaced. This valve chest lining was a new one made slightly thicker than the old one, and it was secured at each end to the old and new diaphragm at each seating by radial screws, so that it formed a tie to help secure the new diaphragm in position.

As soon as all the gear was replaced and the valve chest and cylinder closed up, steam of a low pressure was turned into the valve chest to thoroughly dry the joints in the diaphragm, and they were found to be perfectly tight when the run was made from Hong Kong to Shanghai.

All the work was done at the Hong Kong and Whampoa Dock Co., by Chinese workmen under the direction of English and Scotch foremen, the work being well and quickly done.

The only cause that could be assigned for the breakage is that there must have been a slight shrinkage crack when the cylinder was made, and the continual expansion and contraction due to use had gradually extended it, and during the run with four boilers from Rong Sam Lem the pressure had been sufficient to partially carry away the pieces marked *A* and *B*, figure 1, and cause

the leakage of steam shown on the indicator cards, and this break was completed by the passage to Hong Kong, so that pieces carried completely away. There is no record of anyone having noticed any indication when the cracks started, such as water in the cylinder, that could have caused such an accident.

Since the above accident to the *Concord*, a similar one was discovered by the indicator cards on the sister ship *Bennington*, but in this case the entire diaphragm did not carry away, and it was repaired by patching.

SECTIONS OF VALVE CHEST PORT I.P. CYLINDER

U.S.S. CONCORD.

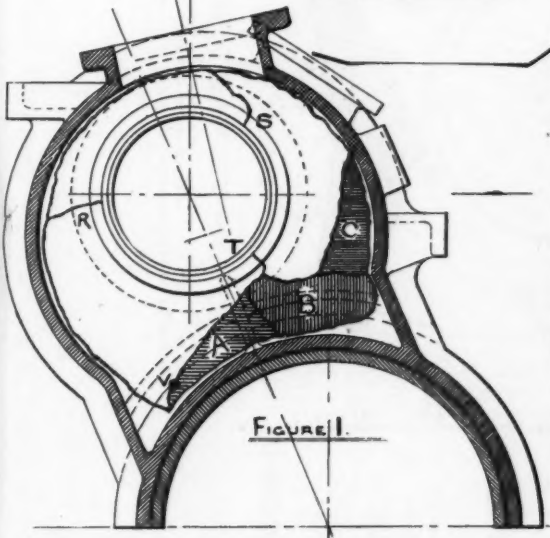


FIGURE 1.

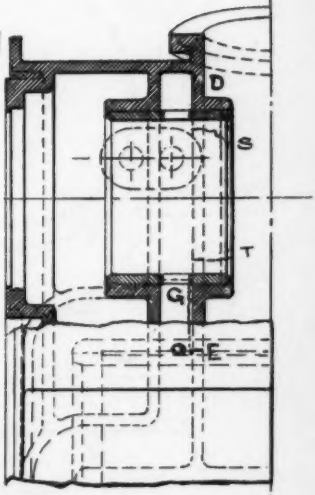
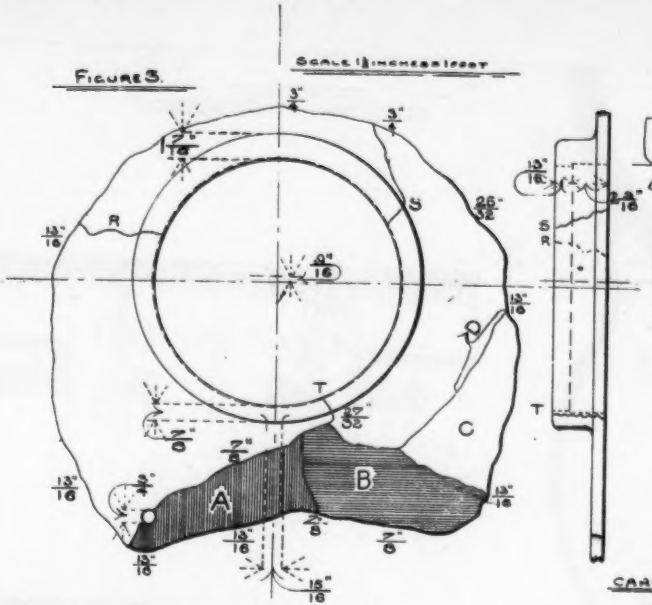


FIGURE 2.

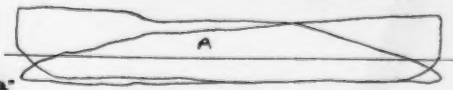
PIECES MARKED A, B. WERE BROKEN ENTIRELY AWAY.
PIECE MARKED C. PARTIALLY BROKEN AWAY.
CRACK EXTENDED ENTIRELY AROUND VALVE CHEST.
RIB CRACKED AS SHOWN AT G.O.
V. CORE ANCHOR.

FIGURE 3.

SCALE 1 INCH EQUALS 1 FOOT



SINGAPORE TO BANKOK, SEPT 28, 1893.



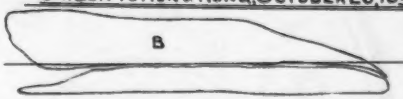
PORT I.P. CYLINDER, REVOLUTIONS 81.

INBOARD

OUTBOARD

FIGURE 4.

SAIGON TO HONG KONG, OCTOBER 26, 1893

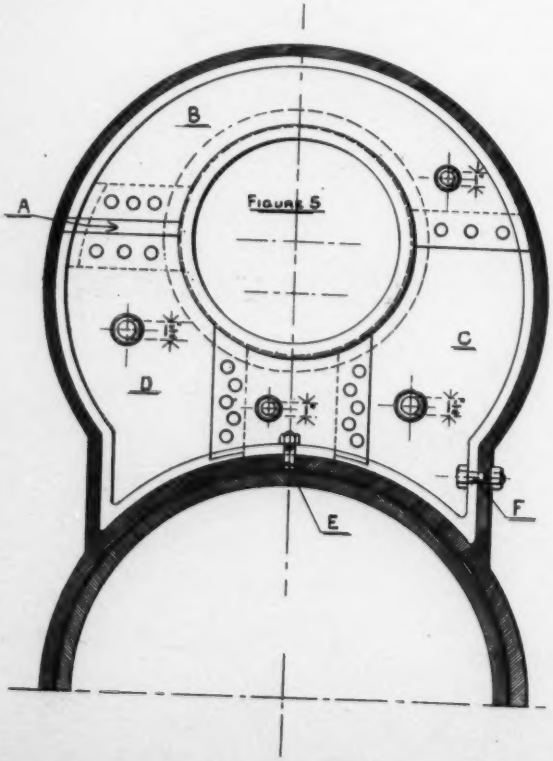


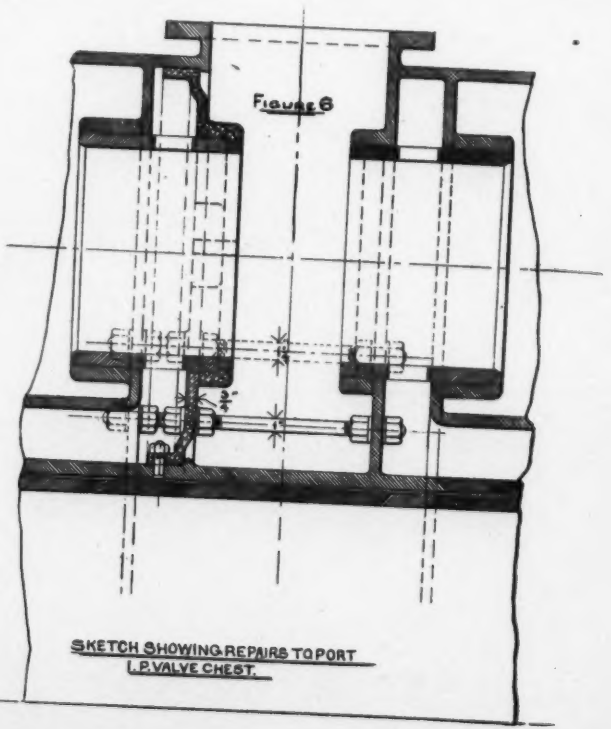
PORT I.P. CYLINDER, REVOLUTIONS 84.

SCALE 16 LBS. = 1 INCH.

CARDS "A" TAKED BEFORE & "B" AFTER BREAK.

SKETCH SHOWING THICKNESS OF WEB, RIB AND RING.
INSIDE OF RING NOT CONCENTRIC WITH OUTSIDE.
PIECES A & B WERE BROKEN ENTIRELY AWAY
AVERAGE THICKNESS OF SOLID METAL AT D 7/8 INCH.
AT R METAL ABOUT 3/8 INCH THICK AT CENTER. CRACKED ON BOTH SIDES.
ALL OTHER CRACKS APPEAR OLD.





SKETCH SHOWING REPAIRS TO PORT
I.P. VALVE CHEST.

SCREW DATA OF THE NEW VESSELS

Name of Vessel.	Displacement.	Mean draught.	Speed.	I.H.P. of each engine.	Revolutions per minute.	Propellers.			Diameter.	Mean pitch.	Pitch ratio $\frac{P}{D}$.	Helicoidal area.	Weight, one propeller.
						Number.	No. of blades.	Material.					
		Ft. In.	*Knots.*						*Feet.*	*Feet.*		*Sq. ft.*	*Tons.*
Atlanta	3,305.	17 11	13.45	2,692.	68.8	1	4	Cast iron.	17.	22.58	1.328	94.68	...
Boston	3,235.	17 8	15.58	3,854.	72.2	1	4	"	17.	24.28	1.428	95 66	...
Chicago	4,543.	19 0½	15.32	2,571.	70.4	2	4	"	15.5	24 5	1.581	77.9	6.408
Charleston	3,557.	17 10½	18 20	3,148.	114 6	2	3	Manganese Bronze.	14.	17.5	1.250	54.7	5.319
Dolphin	1,485.	14 3	15.50	2,185.	74.1	1	4	Cast iron.	13.75	24.0	1.745	70.72	...
Petrel	890.	11 7	11.80	1,050.	126.7	1	3	Aluminum Bronze.	9.75	12.5	1.282	23.5	.989
Baltimore	4,500.	19 10½	20.09	4,915.	116.25	2	3	Manganese Bronze.	14.5	21.5	1.483	57.17	7.857
Bennington	1,700.	14 ...	17.5	1,660.	150.9	2	3	"	10.5	13.7	1.305	26.52	1.879
Concord	1,740.	14 2½	16.8	1,657.	152.4	2	3	"	10.5	13.2	1 257	26.52	1.869
Katahdin	2,183.	15 ...	17.0	2,400.	...	2	3	"	10.5	15 27	1.454	30.18	2.878
Newark	3,980.	18 4	19.0	4,291.	126.9	2	3	"	14.5	18.97	1.308	52 77	7.649
Philadelphia	4,325.	19 2	19.7	4,267.	119.5	2	3	"	14.5	20.33	1.402	57.16	7.913
San Francisco	4,088.	18 9	19.51	4,792.	124.8	2	3	"	13.5	18.75	1.389	57.59	7.498
Yorktown	1,703.	14 ...	16.14	1,603.	156.9	2	3	"	10.5	12.5	1.191	25.42	1.880
Bancroft	832.	11 6	14.37	592.	222.4	2	3	"	7.0	7.75	1.107	15.0	1.002
Brooklyn	9,153.	24 ...	...	8,000.	...	2	3	"	16.5	20.75	1.258	75.74	...
Castine	1,068.	11 9¾	16.03	1,064.	218.8	2	3	"	7.66	8.74	1.141	15.40	.968
Cincinnati	3,183.	18 ...	...	5,000.	...	2	3	"	13.5	15.5	1.148	50.0	...
Columbia	7,375.	22 6	22.8	5,826.	127.7 M. S.	3	3	"	14 0	21.5	1.536	53.28	8.542
				6,083.	133.4				15.0	21.5	1.433	53.70	8.318
Detroit	2,068.	14 5¾	18.71	2,571.	170.1	2	3	"	11.0	13.0	1.182	29.0	2.426
Indiana	10,200.	24 ...	...	4,500.	...	2	3	"	15.5	15.25	0.984	53.85	8.694
Iowa	11,296.	24 ...	...	5,500.	...	2	3	"	16.5	20.0	1.212	75.74	...
Machias	1,068.	11 9⅜	15.46	897.	216.4	2	3	"	7.66	8.86	1.157	15.44	.999
Maine	6,648.	21 6	...	4,500.	...	2	4	"	14.5	16.0	1.103	65.68	8.044
Marblehead	2,050.	14 4¾	18.44	2,432.	176.5	2	3	"	11.0	12.0	1.091	33.3	2.550
Massachusetts	10,200.	24 ...	...	4,500.	...	2	3	"	15.5	15.25	0.984	53.85	8.512
Minneapolis	7,387.5	22 6	23.073	6,573.7	132.52	3	3	"	15.0	22.0	1.47	53.70	...
				7,218 8	132.19				14.0	21.5	1.54	53.28	...
Monterey	4,000.	14 5	13.6	2,493.	162.1	2	3	"	10.17	11.66	1.147	38.88	3.564
Montgomery	2,079.	14 6¼	19.05	2,742.	180.3	2	3	"	11.0	12.74	1.158	29.0	2.426
New York	8,515.	23 10¾	21	8,474.	134.8	2	3	"	16 0	21.0	1.313	69.09	11.782
Olympia	5,570.	20 8⅛	21.69	8,425.	139..2	2	3	"	14.75	19.0	1.288	68.0	9.280
Oregon	10,200.	24 ...	...	4,500.	...	2	4	"	14.75	16.0	1.085	72.0	...
Raleigh	3,183.	18 ...	19.0	5,000.	164.	2	3	"	13.5	15.5	1.148	50.0	...
Texas	6,300.	22 6	...	4,300.	...	2	4	"	14.5	17.33	1.195	66.0	6.628
Vesuvius	930.	10 7½	21.	1,856.	268.9	2	3	"	7.75	9.38	1.210	15.90	.774
Ericsson	120.	4 9	24.	1,800.	412.	2	4	"	4.75	7.67	1.614	8.50	...
Cushing	125.	5 3	17.5	...	328.	2	4	"	4.27	8.42	...	...	...
Gunboat No. 7	1,261.	11 ...	...	1,750.	300.	2	...	...	7.5	...	...	...	...

* Depending on type of engines.

Value of K in $t = \sqrt{\frac{I.H.P. \times f}{R \times n \times b}} \times K.$

R = revolutions per minute.
n = number of blades.

Pitch ratio D	Helicoidal area.	Weight, one propeller.	Slip of propeller in per cent. of its speed.	Value of K in $D = K\sqrt{\frac{I.H.P.}{(P \times R)^3}}$	Value of K in $A = K\sqrt{\frac{I.H.P.}{R}}$ A = helicoidal area.	t. Thickness.	f. Factor.	b. Breadth.	K.	Wetted surface of hull.	Coefficient of augmentation.	Augmented surface.	Augm. surface / Disk area of screws.	Augm. surf. × V³ / I.H.P. V = speed in knots.
	Sq. ft.	*Tons.*				*Ins.*		*Ins.*		*Sq. ft.*		*Sq. ft.*		
.328	94.68	...	12.26	20,060	15.136	10.75	90	37.5	4.922	13,657	1.268	17,317	76.3	15,650
.428	95 66	...	9 94	20,110	13.094	10.73	90	37.5	3.608	13,522	1.268	17,146	75.5	16,830
.581	77.9	6.408	9.99	23,300	13.716	8.00	100	33.5	2.658	21,023	1.204	25,312	67.1	20,040
.250	54.7	5.319	8.04	22,370	10.420	7.50	100	33 5	2.051	17,154	1.161	19,915	64.7	19,010
.745	70.72	...	11 68	22,060	13.024	9.12	100	30.75	4.368	10,580	1.132	11,976	80.6	20,410
.282	23.5	.089	24.5	19,860	8.163	3.50	100	20 0	.887	6,681	1.242	8,297	111.1	12,980
.483	57.17	7.857	18.55	25,550	8 792	8 94	90	43.5	2.741	20,483	1.215	24,887	75.4	20,530
.305	26.52	1.879	14.22	24,220	7.996	5.50	90	22.62	2 073	10,832	1.189	12,879	74.4	20,790
.257	26.52	1.869	15.39	23,270	8.043	5.50	90	22.62	2.098	10,932	1.189	12,998	75.1	18,600
.454	30.18	2.878	24 79	23,500	7.545	6.25	90	27.87	2.268	11,038	1.321	14,581	84.2	14,920
.308	52 77	7.649	20.02	26,140	9.075	9.50	90	38.5	3.425	17,956	1.194	21,439	64.9	17,130
.402	57.16	7.913	17.83	26,580	9.506	9.00	90	43.23	3.270	19,976	1.215	24,271	73.5	21,740
.389	57.59	7.498	15.51	22.070	9.294	9 375	90	48.5	3.700	18,232	1.194	21,769	76.0	16,870
.191	25.42	1.880	16.60	22,780	7.953	5.50	90	22.5	2.221	10,824	1.189	12,869	74 3	16,880
.107	15.0	1.002	15.50	20,590	9.194	3.40	90	21.75	3.148	6,690	1.237	8,275	107.5	20,740
.258	75.74	...	24.28	25,550	9.618	10.37	90	48.0	2.839	31,489	1.221	38,448	89 9	19,220
.141	15.40	.968	15.05	19,640	6.984	4.12	90	19.50	2.269	7,293	1.207	8,803	95 4	17,040
.148	50.0	...	24.26	24,470	9.055	7.50	90	41.0	2.521	16,664	1.160	19,330	67.5	13,260
.536	53.28	8.542	15.85	26,390	7.888	9.50	90	42.0	2.769	29,962	1.158	34,696	68 4	19.740
.433	53.70	8.318	19.44	29,540	7 952	9.75	90	39.0	2.710					
.182	29.0	2.426	14.26	22,560	7.459	5.25	90	23.75	1.444	12,415	1.190	14,774	77.7	18,820
.984	53.85	8.694	22.13	19,930	9.082	8.87	90	38.25	2.853	30,300	1.683	50,994	135.1	19,120
.212	75.74	...	27.94	23,750	10 833	10.37	90	48.00	3.520	31,882	1.523	48,556	113 5	18,080
.157	15.44	.999	18.29	21,470	7.584	4.12	90	19.50	2.662	7,293	1.207	8,803	95.4	18,130
.103	65.68	8.044	18.43	20,980	11.249	7 87	90	36.50	2.947	24,753	1.355	33,113	100 3	18,080
.091	33.3	2.550	11.57	21,740	8.971	6.12	90	26.00	2 356	12,352	1.190	14,699	77.3	18,950
.984	53.85	8.512	22.13	19,930	9.082	8.87	90	38.25	2.853	30,300	1.683	50,994	135.1	19,120
.147	53.70	...	18.58	20,124	7.628	9.50	90	42.0	2.491					
.154	53.28	...	20.15	26,751	7.200	9.75	90	39.0	2.307	29,903	1.158	34,630	68.26	20,886
.147	38.88	3.564	27 08	16,740	9 914	5.75	90	35.0	2.508	16,794	1.910	32,076	197 6	16,180
.158	29.0	2.426	15.96	23,130	7.430	6.25	90	23.75	2.033	12,427	1.190	14,788	77 8	18,640
.313	69.09	11.782	24.82	23,330	8.714	11.12	90	47.62	3.122	30,600	1 251	38,280	95.2	20,915
.288	68.0	9.280	16.93	21,860	8.741	7.87	90	42.00	1.433	24,427	1.190	29,068	85.1	17,580
.085	72.0	...	25.78	20,380	12.143	7.50	90	38.50	2.738	30,300	1.683	50,994	149.6	19,120
.148	50.0	...	24.26	24,470	9.055	7.50	90	41.0	2.521	16,664	1.160	19,330	67.5	13,260
.195	66.0	6.628	19.18	21,760	11.163	8 62	90	33.25	3.141	22,498	1.380	31,047	94.0	17,740
.210	13.90	.774	20.84	22,790	6.052	4 375	90	18.	1.664	8,198	1.114	9,132	96 8	22,165
.614	8.50	...	35.75	...	...	...	...	...	...	2,244	1.058	2,374	67.0	18,230
...	...	...	...	...	...	...	...	...	...	1,980	1.058	2,094	...	...
...	...	...	...	...	...	...	...	...	...	9,193	1.123	10,322	116.8	16,190

type of engines.

AIR PUMPS.

CONTINUATION OF DISCUSSION.

N. P. Towne, Esq.—I have read with a great deal of interest Mr. Bailey's very able and instructive paper on air pumps, and can add but little to the information he has given us on the subject. I may, however, suggest that we may continue with advantage our investigations into the subject of the *modern* air pumps, leaving the cranked pumps to become merely a matter of history.

If we take an indicator diagram from a water cylinder of an air pump and reduce the card of its actuating cylinder to the corresponding pressure on the air pump piston, and place one over the other, we can readily see what has to be overcome in the cranked pump, and what is done with the direct-acting pump.

I have taken here a card from the direct-acting air pump of a naval vessel, and over it have placed the composite cards taken from the bottom and top ends of the steam cylinders of the same pump; and again have taken the cards from the engines of a cranked pump and applied them in the same manner. These arrangements will show graphically why a cranked air pump cannot be as steady and reliable as one of the direct-acting class. The cards are taken from one of the cranked pumps mentioned in Mr. Bailey's paper.

As the quantities of water discharged are nearly the same per minute, and the number of strokes were as 142 to 14½, there could not have been as much water discharged each stroke, providing the pump was discharging equal amounts each stroke, but as it is a known fact that a quick working pump works intermittently, I have assumed this card for the maximum.

From the diagram of the direct-acting pump it can be seen that at no time does the cylinder pressure referred to the air

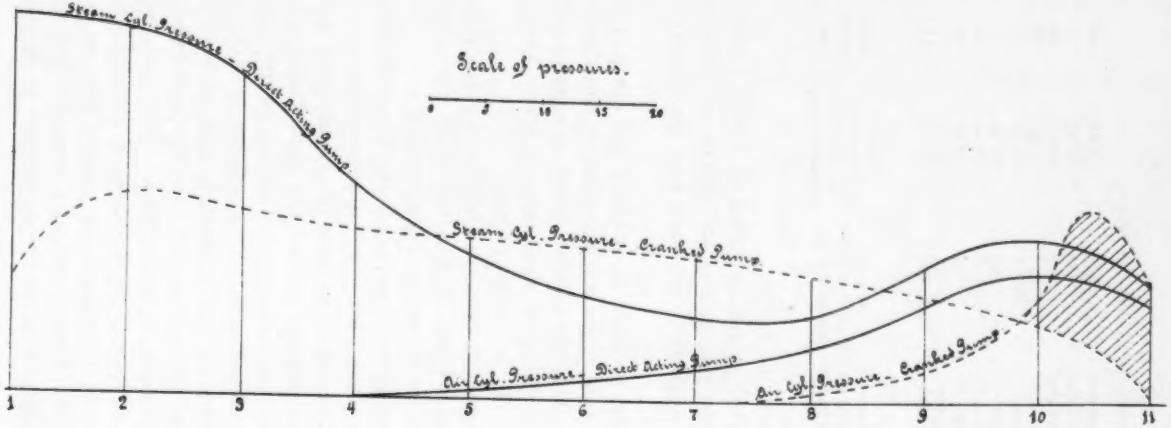
pump piston fall below the water and air pressure on that piston, so that there is no reason, independent of mechanical defects, why the pump should not continue its motion. At the end of the stroke where the pressures approach each other, observation shows that there is a slacking of the speed, and at times almost stopping; but it never does stop, but continues its quiet gait without any care or attention except the ordinary care given to good machinery.

If we compare the composite diagram of the cranked pump we immediately see that there is a certain area which varies according to the amount of water discharged, when the pressure on the water piston is greater than that on the combined pistons of the steam cylinders. This pressure must be overcome or the pump will stop, and, as Mr. Bailey has intimated, we will require a fly wheel heavier than the rest of the pump to make a steady motion.

If a lighter fly wheel is used, the pump must be driven faster than necessary to do the work or it stops. No arrangement of valve can be made that will more than partially overcome this fatal objection; for, as the greatest resistance takes place when the engine is near the center, if the momentum of the fly wheel will not carry the crank over, the pump must stop. The only cranked air pump I have in mind that works at the proper speed without trouble is one on a steamer built by Cramp & Sons; but this efficiency is brought about by carrying two fly wheels 7 feet in diameter, each weighing 1.70 tons, which would be utterly inadmissable in a naval vessel.

This condition never can occur in the direct-acting pump, for the pressure on the steam piston will rise if it slows below the adjusted speed, and the pump will move on again, though at a slower rate than at the beginning of its stroke.

The crank pump cannot ease itself down; to receive the shock of a sudden influx of water there must, even with a fly wheel of proper weight, be a sudden and heavy concussion, necessitating an increase in the strength of the machinery to resist the shock, and a constant watchfulness on the part of the engineer to start the pump again or to pick up the pieces.


Steam Cyl. Pressure - Direct Acting Pump
Scale of pressures.
0 5 10 15 20
Steam Cyl. Pressure - Cranked Pump
Air Cyl. Pressure - Direct Acting Pump
Air Cyl. Pressure - Cranked Pump
1 2 3 4 5 6 7 8 9 10 11

A better distribution of the steam than can be obtained by a single valve on a crank pump might be made by using the Meyer cut off, the main valve following full stroke, and the cut off so adjusted that it would cut the steam off at quarter stroke and open again at one-half or five-eighths. Still, this would be as wasteful as following full stroke, the only advantage being a pressure approximate to the resistance at different parts of stroke.

As regards economy, there is no doubt that the cranked pump can be made more economical per stroke, but the high speed that has to be maintained to keep the pump going, and the increase of power necessary to drive the pump itself, will render its expenditure of steam per I.H.P. of main engine much greater.

I append a table showing the comparative percentage of power required to drive the air pumps of various ships.

The direct-acting pump is lighter, takes up less space, is less costly in expenditure of steam, is equally accessible, is less liable to break downs, and is cheaper to build.

I am of the opinion that, when nothing better was known, it was our duty to make the cranked pump as efficient as possible, but that now, in view of the repeated trials of each class of pump, it is a misdirection of talent to design a new cranked pump for ordinary cases.

I myself was intimately connected with the designs of many cranked air pumps, but after seeing the, to my mind, immense practical superiority of the direct-acting pump, I cannot as an engineer hesitate in my choice.

Name of ship.	Air pumps, direct-acting or cranked.	Average I.H.P. main engines on trial.	Average I.H.P. air pump engines on trial.	Per centage ratio.	Vacuum.
New York.....	Direct.	16 947	38.74	.23	25.40
Columbia.....	Direct.	17.991	56 44	.31	25.23
Minneapolis.....	Direct.	20.336	33.17	.16	25.50
Olympia.....	Cranked.	16 850	54.00	.32	25 26
Monterey.....	Direct.	4.987	36.53	.76	26 41
San Francisco...	Cranked.	9 581	107.71	1 12	25.90
Marblehead.....	Cranked.	4,863	31.60	.65	26.05
Charleston.....	Cranked.	6,316	42.85	.68	26.12
Castine.....	Cranked.	2,128	14.07	.66	25.30
Machias.....	Cranked.	1.794	17.94	1.00	25.70

Omitting the *Olympia's*, which is a three-cranked air pump, this table shows the average ratio of a direct acting to be .365 compared with .822 of the cranked pump, making the cranked pump 2.26 times as expensive as the direct acting.

Assistant Engineer J. S. Porter, U. S. Navy.—The Bailey air pump, described in the last number of the JOURNAL, was tested at the New York Navy Yard during the latter part of August, under instructions issued by the Bureau of Steam Engineering, and the result was so satisfactory that a description of the method of conducting the test, and a report of the results, ought to find an appropriate place in the discussion of the air-pump question.

The pump tested is the one built for the engines of one of the third-class torpedo boats of the *Maine*, and has two horizontal double-acting cylinders, each 3 inches in diameter and $3\frac{1}{4}$ inches stroke. When in position in the boat, it is to be driven by two eccentrics keyed on the forward end of the main engine crank shaft, but during the test it was mounted on a bracket placed on the bearing support of the dynamo in the dynamo room of the machine shop, and the two driving eccentrics keyed to the end of the dynamo shaft. This shaft has a disconnecting coupling, by means of which the dynamo itself was thrown out of gear during the trials, and the engine that runs the dynamo used to operate the air pump. The air pump was connected with its condenser, which was placed on a wooden frame work, in the same relative position that it will occupy when in position in the boat. It discharged into a wooden tank through a 2-inch pipe, which, after entering the tank, rose to a height of three feet and had its end closed by a cap. The water, air and vapor were discharged through eight vertical slits in the upper end of the pipe, the combined area of the slits being three square inches. Over this discharge pipe was placed an inverted tin tank for the purpose of entrapping all the air discharged. This tank was weighted at the bottom so as to float upright, and had two guides placed vertically on opposite sides. A brass plate with twenty $\frac{5}{32}$-inch holes was soldered to the middle of the upper end of the tank in order to measure, as hereinafter described, the quantity of air

discharged. Wooden plugs were provided for each hole, so that the escape of air could be regulated.

Area of cross section of tank, square feet, .	1.3963
Weight, pounds, ...	27.25
Volume per inch of depth, cubic feet, . .	.1164

To supply water to the condenser, another tank was provided having a pipe connecting with the steam side of the condenser; this pipe was fitted with a Worthington water meter with a $1\frac{1}{2}$-inch outlet, between which and the condenser was a stop valve for regulating the flow of water. A 3-inch overflow pipe connected the supply and the discharge tanks, so that the same water was used over and over during the trials. Attached to the condenser were an air cock, a vacuum gauge, and a thermometer. All the instruments used were standardized.

Before beginning the test, the pump was carefully examined and moved by hand. The supply and discharge tanks were filled with water, and the tin tank placed in position and then raised to a certain height, all the plugs in the upper end being out. The plugs were then put in, and the height at which the tank floated was marked; one plug was then removed, and the distance the tank sunk in one minute, impelled by its own weight, read; the area of the cross section of the tank being known, the volume of air escaping through one hole in one minute was readily determined. In this manner it was found that with one hole open, the tank sunk 5.505 inches (the mean of four observations) in one minute; that is, $5.505 \times .1164 = .641$ cubic feet of air escaped per minute. During the trials, just enough holes were kept open to keep the tank floating at approximately the same level.

The first experiment, which was made on the 22d of August, lasted one hour, and consisted in starting the pump as slowly as possible—104 revolutions per minute—and increasing its speed gradually to 700 revolutions, the water discharged being increased from 0 to about 1 cubic foot per minute. No air was admitted to the condenser during this experiment, but owing to difficulty in regulating the feed-water heater from which the

supply was taken, the temperature of the water was somewhat higher than was desired. The vacuum obtained was from 23 to 23¾ inches, and the reason for it being so low was apparently due to the high temperature of the water supplied.

Before beginning the second experiment, the pump was run for thirty minutes at about 700 revolutions per minute, taking about 7.25 gallons of water per minute at exactly 120 degrees Fahrenheit, all other conditions remaining as prescribed for the first experiment. The vacuum attained was exactly 26 inches, which was reached with ease in less than two minutes after starting the pump; and it remained steady at 26 inches during the entire period. This vacuum of twenty-six inches was used as a basis for the remaining experiments.

During this and the subsequent experiments the supply and discharge tanks were filled with cold water, and heated to the required temperature by blowing steam into them through a steam hose.

The results of this experiment are tabulated and appended to the table for the first experiment, and marked 1*a*.

Only about one-fifth of a cubic foot of air and vapor was discharged per minute.

At the beginning of the second experiment the air cock on the condenser was opened just enough to lower the vacuum one inch, that is, to twenty-five inches, the other conditions remaining the same as in the first experiment. The third and fourth experiments were made under similar conditions, except that, in each, the vacuum was reduced in the same manner as for the second experiment, one inch below what it was during the preceding experiment.

For the fifth experiment everything was put under the same conditions as obtained during the second, that is, with twenty-five inches of vacuum; but the quantity of water supplied was gradually increased from one to a little more than four cubic feet per minute, the purpose being to test the pump under the most adverse conditions.

During all of these experiments, occupying one hour on the 22d of August, and four hours and twenty minutes on the 23d,

the pump worked well. There was no abnormal pounding or other noise about the valves, even during the last test, and the whole gear worked very smoothly. For four hours and twenty minutes the pump made an average of 1,404 strokes per minute, and when examined after the completion of the test it showed no signs of any undue strain, and was in good condition in every way.

In the accompanying tables, giving the record of the several experiments, *R* represents revolutions per minute; *V*, vacuum in condenser; *H*, holes open in gas tank; *W*, water discharged in gallons per minute; *A*, air discharged in cubic feet per minute; *Tc.*, temperature of condenser, Fahrenheit; *Td.*, temperature of discharge, Fahrenheit.

EXPERIMENT No. 1, AUGUST 22, 1894. BAROMETER 30.35.

Time.	R.	V.	H.	W.	A.	Tc.	Td.
3·00 P. M.	104.	25.	½	.....	...	.....	.....
3·10 P. M.	128.	24.	½	2.89	.32	127.	142.
3·20 P. M.	295.	23.	½	5.24	.32	140.	142.
3·30 P. M.	426.	23.25	½	6.21	.32	138.	140.
3·40 P. M.	548.	23.50	½	7.26	.32	136.	137.
3·50 P. M.	645.	23.75	½	7.25	.32	133.	135.
4·00 P. M.	716.	23.75	½	7.33	.32	132.	134.
Averages	459.6	23.75	½	6.03	.32	134.3	138.3

NOTE.—One hole was open in tank one-half the time.

EXPERIMENT No. 1a, AUGUST 23, 1894. BAROMETER 30.41.

Time.	R.	V.	H.	W.	A.	Tc.	Td.
9·40 A. M.	689.	26.	⅓	7.14	.2	118	120
9·50 A. M.	703.	26.	⅓	7.14	.2	118	120
10·00 A. M.	720.	26.	⅓	7.48	.2	118	120
Averages.	704	26.	⅓	7.25	.2	118	120

NOTE.—One hole open in tank one-third the time.

EXPERIMENT No. 2, AUGUST 23. 1894. BAROMETER, 30.43.

Time.	R.	V.	H.	W.	A.	Tc.	Td.
10·10	720.	25.	1⅓	7 48	.77	118.	120.
10·20	700.	25	1⅓	7 25	.77	118.	120.
10·30	685.	25.	1⅓	7.85	.80	118.	120.
10·40	718.	25	1	7 85	.64	118.	120.
10·50	688.	25.	1⅓	7.48	.80	117.5	120.
11·00	703.	25.	1⅓	7.85	.77	117.	119 5
Averages	702.3	25.	1⅓	7.63	76	117.75	120.

NOTE.—Air cock on condenser opened so as to lower vacuum one inch from that obtained in Experiment No. 1*a*. One hole open in tank, and another open at intervals.

EXPERIMENT No. 3, AUGUST 23, 1894. BAROMETER 30.42.

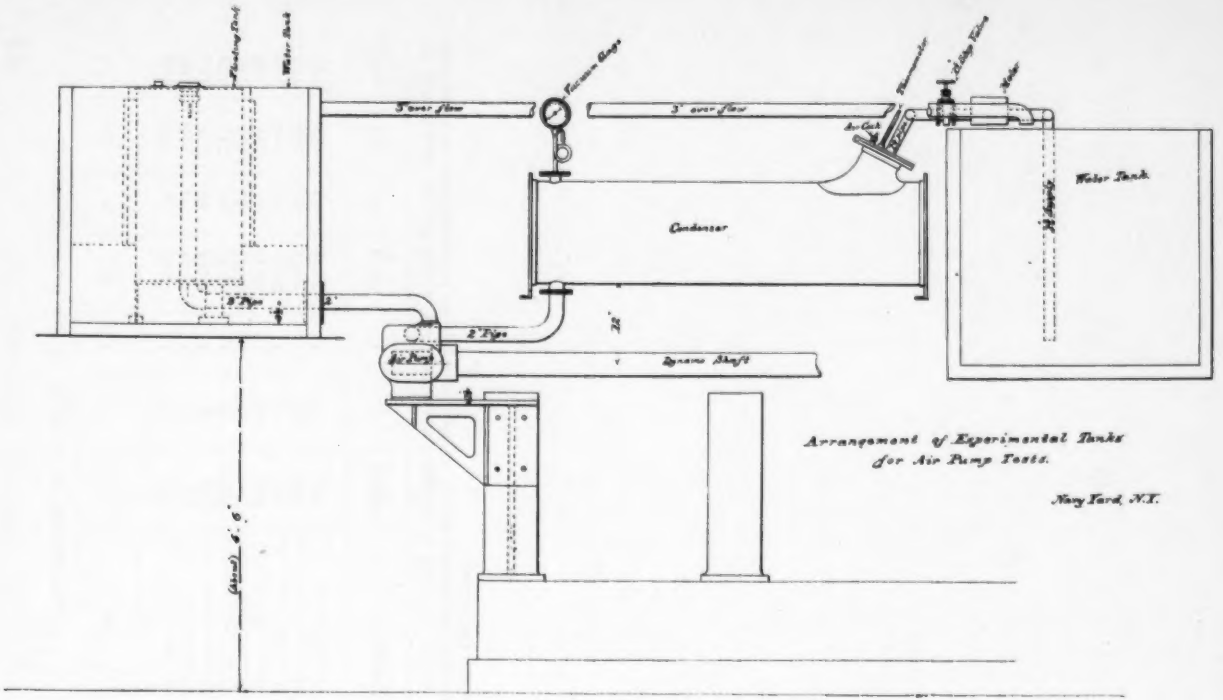
Time.	R.	V.	H.	W.	A.	Tc.	Td.
11·10	709.	24.	2	7.48	1.28	11,.	119.5
11·20	690.	24.	2	7.85	1.28	117	119.5
11.30	708.	24.	2	7 85	1.28	116.5	119.0
11·40	699.	24.	2⅓	7.85	1.49	116.	119 0
11·50	710.	24.	2⅓	7 48	1 44	116.	118.5
12·00	707.	24.	2⅓	7.48	1.44	115.	118.
Averages	703.8	24.	2⅓	7.66	1.37	116.2	118.9

NOTE.—Air cock on condenser opened so as to lower vacuum one inch from that obtained in Experiment No. 2 Two holes open in gas tank, and another open at intervals.

EXPERIMENT No. 4, AUGUST 23, 1894. BAROMETER, 30.43.

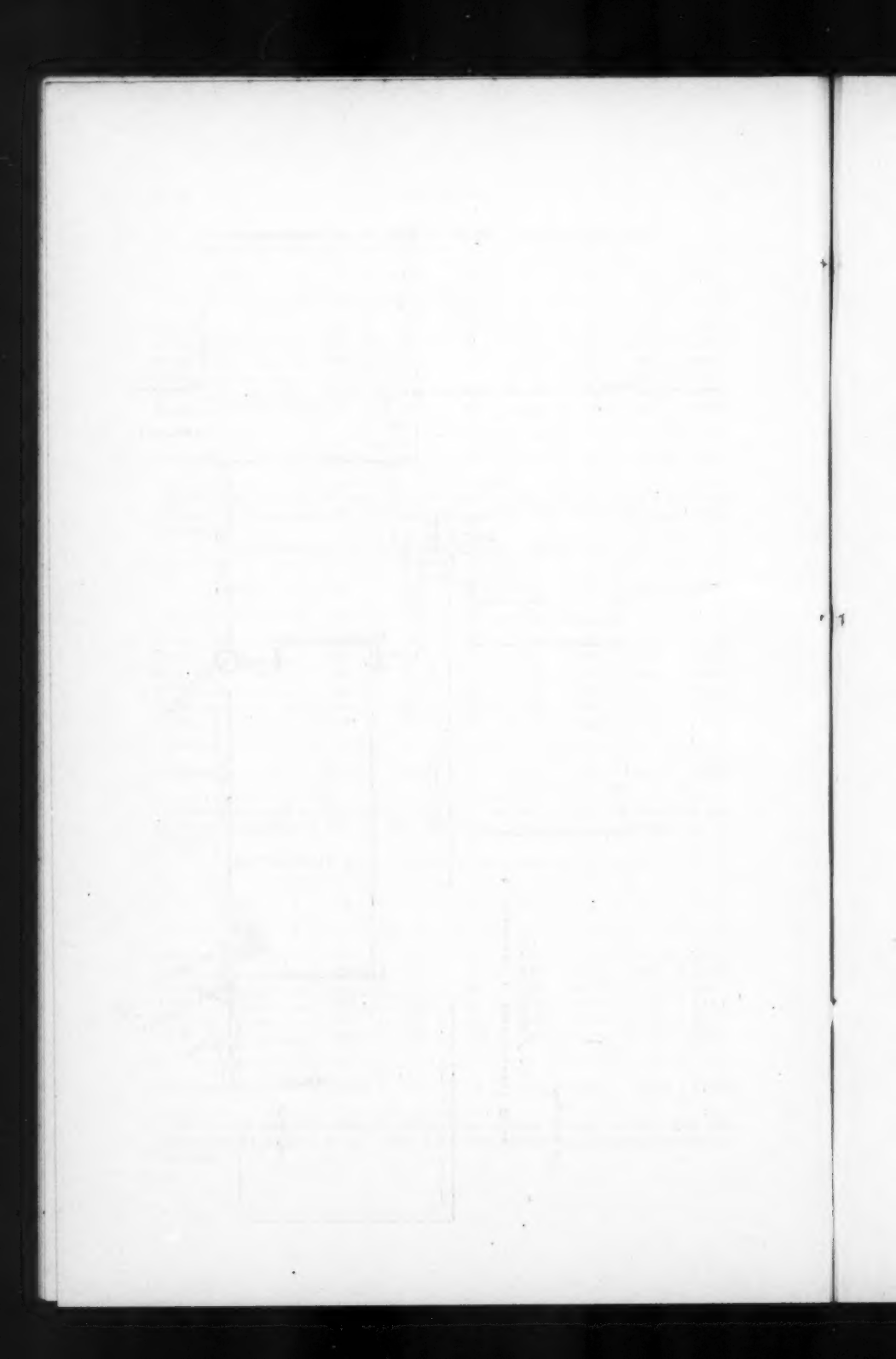
Time.	R.	V.	H.	W.	A.	Tc.	Td.
12·10	712.	23.	3⅓	7 48	2.13	114.5	117.
12·20	707.	23.	3⅓	7.85	2.13	114.	116.
12 30	691.	23.	3⅓	7 55	2 08	114.	116.
12·40	687.	23.	3⅓	7.48	2.03	115.	117.5
12·50	711.	23.	3 1/16	7.48	1 99	114.	116.
1·00	693.	23.	3 1/16	7.48	1 99	115.	117.
Averages	700 2	23	3⅓	7.54	2 06	114.4	116.6

NOTE.—Air cock on condenser opened so as to lower vacuum one inch from that obtained in Experiment No. 3. Three holes were opened in gas tank and another at intervals.



Arrangement of Experimental Tanks for Air Pump Tests.

Navy Yard, N.Y.



EXPERIMENT No. 5, AUGUST 23, 1894. BAROMETER, 30.42.

Time.	R.	V.	H.	W.	A.	Tc.	Td.
1·05	700.	25.	1	13.46	.64	116.	118.
1·10	701.	25.	1	15.48	.64	116.	118.
1·15	699.	25.	1	16.68	.64	117.	119.
1·20	688.	25.	1	16.83	.64	117.	119.
1·25	709.	25.	1	18 55	.64	117.	119.
1·30	693.	25.	1	28.42	.64	116.	118.
1·35	711.	25.	1	29 32	.64	116.	118.
1·40	700.	25.	1	30 82	.64	116.	118.
1·45	714.	25.	1	30.67	.64	116.	118.
Averages	701 5	25.	1	22.25	.64	116.3	118.3

NOTE.—Air cock on condenser closed until the vacuum was the same as that obtained in Experiment No. 2. Water discharged was increased slowly to about thirty gallons per minute.

ELECTRIC WELDING.

By Mr. Benjamin Alfred Dobson.

[Read before the British Institution of Mechanical Engineers]

Experience in Electric Welding.—Practical everyday working for nearly three years of the process of welding by electric force enables the author to give certain indications and appreciations of the method considered as a practical workshop operation. During this period his firm has had two machines in operation, worked from the same generating dynamo, and employed on different classes of work: one is specially arranged for piecing bar iron and steel; and the other and smaller machine for special classes of work of a more delicate description, such as brazing and the piecing of clean-finished work, where the fire heat would have destroyed the quality of the work on the adjacent material.

Mechanical Power.—The statement made with regard to the requisite mechanical power placed great difficulties in the way at first, as it was found that this power had been much understated. Having something like 35 indicated horse power to spare on a certain engine, and understanding that 30 horse power would be the utmost wanted in order to piece a 2-inch round bar, the author determined to drive the dynamo from this engine, particularly as it was in close proximity to the smithy and stretching shed, where this piecing was previously effected by means of the ordinary smith's hearth. By this practical test it was found that not 30 horse power, but as much as 80 horse power, seemed to be required for the larger sizes; and until this was understood, the engine was frequently stopped from want of steam, occasioning great loss and inconvenience. The company having control of the welding machine suggested that they should supply a semi-portable engine and boiler; and that this should be tried, with the option of purchase after a certain length of

time, if approved. This was agreed to, and a portable engine, capable of working up to 100 indicated horse power with 80 pounds pressure, was supplied and placed at a distance of about 45 yards from the welding machine. This got over the difficulty of power, but was, of course, more expensive on the score of separate attendance and other cost. But even with this engine it was found that, when piecing the larger diameters—and as yet nothing over 2¼ inches had been pieced—if the work was to be done within a reasonable time, the engine was seriously checked in speed. It was, therefore, with a view to be certain as to the basis of calculation for the necessary expenditure on driving power that the experiments which follow were conducted.

After some months' working with the portable engine, it was proved satisfactorily that the process was a practical one, and, so far as the results to the author's firm were concerned, a success. As considerable enlargements were about to be made to the establishment, a portion of a large dynamo room for electric lighting purposes was set apart for the welding dynamo and exciter; the distance of the leads from the dynamo to the welding machine was approximately 100 yards. Having a quick-running vertical engine of the kind made by Messrs. Fleming and Ferguson, making 140 revolutions per minute, with an extra heavy flywheel and abundance of surplus power, the author has been able to work the larger diameters without affecting the steadiness of the arc lamps driven off the same engine; and as the load will vary 80 horse power in the tenth of a second, this result speaks well for the arrangement of the engine and for its governing powers. The greatest variation in voltage of the lighting dynamos has been two volts.

Electric Welding Process —The following account of the principle of electric welding is taken verbatim from a paper prepared for a former meeting of this Institution by Mr. W. C. Fish, on the Elihu Thomson electric welding process:

"*Principle of Electric Welding.*—Every substance, whatsoever be its physical nature, is heated when traversed by an electric current, and the law defining the quantity of heat so produced is as precise and as clearly ascertained as that of gravitation. The pro-

duct C^2R—that is, the square of the current flowing, multiplied by the electrical resistance of any considered portion of the circuit—is directly proportional to the heat units therein produced. For a continuous current, the resistance of an infinitesimal length of any conductor is inversely proportional to the area of its cross section, and in metals increases with increase of temperature. Thus, in iron the resistance increases some tenfold with a rise of temperature from 0 degree to 1,000 degrees Cent. For alternating currents, which are usually employed in welding, the resistance of a conductor no longer varies inversely as its cross section; but this divergence may be neglected without error in the description of the process, if not in the design of the welding machine."

Dynamo.—The Thomson-Houston welding dynamo is an alternating-current machine. The field magnets project inwards from a cast-iron frame having six pole-pieces. Its speed is 1,000 revolutions per minute, and it gives at full load a current of 200 amperes at 300 volts, having a frequency of 100 complete alternations per second. The machine is excited from a continuous-current dynamo giving 40 amperes at a pressure of 110 volts. The large welder is capable of piecing iron or steel bars up to 2 inches in diameter.

Transformer.—The primary coils consist of 41 turns of 0.452-inch copper wire; these are coiled round an iron core formed of thin sheet iron plates bolted together. The secondary circuit consists of a single massive copper tube $1\frac{3}{4}$ inches in diameter inside and $3\frac{3}{4}$ inches outside, passing through the center of the core, and connected at the two ends with massive castings $6\frac{1}{2}$ inches broad by 3 inches thick, which support the welding clamps; one clamp is kept stationary during the welding, and the other is movable. The pressure is obtained by a screw and hand wheel, forcing the movable clamp towards the fixed clamp.

Elihu Thomson Welding Process.—It has just been pointed out that the heating effect of the passage of electric energy through a bar of any particular resistance is proportional, not to the amount of energy, but to the square of the current simply. In order, therefore, to obtain the greatest heating effect with a given

amount of energy, it is advisable to use a very large current at a very small pressure. With this object an alternating current is employed in the Thomson process, and transformed down from something like 300 volts to 1 volt, or even a fraction of a volt. This reduction in pressure is accompanied by an exactly proportional increase in current, and the heating effect of the process is due to the passage of this enormous current through the bar which is to be welded. The bar itself is held between two clamps of copper having a small resistance, and the portion of the bar to be heated for welding is that which lies between the two clamps, and which always has a much greater resistance than the clamps themselves or any other portion of the circuit. Even, therefore, if a solid bar be held between the two clamps, it becomes heated somewhere between the points at which it is held. If, however, as is the case for welding, the bar is not a solid one, but has a break in it at the point where it is to be welded together, then the greatest resistance in the circuit is at the surface of this break, where the contact is imperfect. Heat is developed here at once, and the surfaces being continuously pressed together by special apparatus, the metal as it softens is squeezed into closer contact, and eventually the two original separate pieces are thereby welded together. The resistance at the original break would, of course, become diminished as the metal becomes continuous by welding, if it were not even more increased by the rise of temperature and the consequent fall in conductivity. In consequence of the latter, however, the temperature of the metal at the weld continues to rise throughout the process until the current is finally cut off. The increase of resistance with temperature automatically necessitates also the uniform heating of the entire cross section of the weld, because any cooler portions will be traversed by a proportionately increased flow of current until uniformity of temperature is obtained.

Good and Bad Welds.—It must not be imagined that a good weld can always be made by pressure alone. No doubt if the material were perfect in character and thoroughly homogeneous, this might be the case. The iron and steel of commerce are not perfectly pure; and in order to make certain that the work may

be subsequently depended upon, it is advisable that the burr formed by the pressure should be reduced by hammering in swages. The machine used by the author has a screw and handwheel for supplying the pressure requisite to give the welding action, and this machine has been found powerful enough, so far as its mechanical arrangements are concerned, for piecing iron and steel bars up to 2 inches in diameter. The distance apart of the clamps—or, to put it in another way, the length of the projection of the material to be pieced—varies according to the nature of the material and the diameter or area of the weld to be made, and is, as can be well understood, proportionately less for the larger sizes and greater for the smaller. There are limits, of course, in both directions; but these limits are well within the machine itself, and a short practical experience teaches the workman the distance he ought to set his machine. Roughly speaking, for the smaller sizes the projection should be about three times the diameter of the piece, and for the larger sizes twice the diameter. When welding pieces of different diameter, the center of resistance can be brought to the point of contact by varying the projection of the different diameters, and thereby equalizing the resistance in the projecting portions. Thus in piecing 1-inch and 1½-inch bars, the 1-inch bar might have to project some 3 inches, and the 1½-inch bar 2 inches, in order to bring the center of resistance to the point of contact. This principle of difference of projection applies also when piecing metals of different quality. It is found in practice that the current should not be turned on to its full strength at the commencement of the operation; if this is done, the material under treatment is unnecessarily damaged, and the general life of the machine itself is injured. As the surfaces in contact become heated and the resistance is increased, the rheostat or regulator of power, or choking coil, is gradually turned to increase the volume of current; and immediately before taking out of the clamps for the purpose of swaging, the full power required is turned on for a second or two.

Method of Working.—The method of working is somewhat on the following lines. The main carrying the current to supply

the exciting coils of the alternator is conducted to the room in which the electric welder is placed. The main is attached to the terminal of a rheostat or resistance coil, and a return main is connected to the other terminal and is returned to the alternator, and from this another main is led back to the exciter. The rheostat, now being in series with the exciting coils, governs the current of excitation, and thus controls the output of the alternator. A double-pole switch has one pole connected with the primary main leading to the primary coil of the electric welder, and the other pole connected with the exciting-current main leading to the rheostat; so that this switch breaks the exciting circuit and also the primary circuit at the same time. When two pieces are ready to be welded, the double-pole switch is switched in, and the attendant adjusts the rheostat until the desired heat is obtained.

The ordinary surfaces of bars, whether cut by shears or broken with the chisel and hammer, are found sufficiently uniform to permit of welding, without further preparation. Should there be dirt or rust upon the surfaces, it is easily expelled when the metal is sufficiently soft to allow of the end pressure of the screw necessary to form union, and the dirt, scale or oxide makes its way to the exterior.

Work Done.—In common practice at the author's works the following materials have been heated, and the under-mentioned work has been performed. Welding of steel of every quality, iron of every description, from crown to best roller iron and charcoal iron, steel and iron together, wrought iron and cast iron; different diameters of the same and different materials. Riveting in many varieties; work which previously had to be riveted cold, and which consequently left the strength of the parts uncertain, is now done easily and certainly with the requisite heat. The piecing of countershafts and lathe spindles, where the question of exactness of length is of the utmost importance; screwing taps, rollers and spindles broken in the neck bearings, and brazing of all descriptions, have all been successfully treated. The alloys which have been tried have been done more for the purpose of experiment than for any

useful end, and were not successful, owing to there not having been time to persevere sufficiently for ascertaining the precise temperatures and conditions under which the process could succeed.

Power Required for Electric Welding.—These tests have been confined to the welds required in everyday work, and have varied from ½-inch steel and iron to 2-inch, as shown in Table I. The measurement of the alternating-current power supplied to the welding transformers is attended with some little difficulty, owing to the short space of time during which the current and electromotive force are practically steady. As, also, every piece of iron varies in resistance, though cut from the same bar, the power registered is continually varing in the welding of bars of the same diameter. Another cause accounting to some extent for the different powers obtained with the same size of shafting, is that the rheostat is not always worked from the same segment of the coils, through the adding or deducting of the resistance, and consequently causes a greater or less excitation of the field of the alternator, thereby producing a greater or less electromotive force.

A Siemens electro-dynamometer was connected in series with the thick-wire coil of a Siemens watt-meter, the latter being in series with the primary coil of the electric welder. Connected across the terminals of the welder was the thin-wire coil of the watt-meter, in series with a non-inductive high resistance. A Siemens voltmeter, for the measurement of alternating volts, was also connected across the terminals of the welder. By this means the virtual volts and the virtual amperes were estimated with sufficient accuracy; and at the same moment a reading was taken from the watt-meter, giving the true watts absorbed in the transformer. At the time of taking the instrument readings, indicator diagrams were taken from the engine, which afford a considerable check on the results obtained from the watt-meter. In order to estimate accurately the power taken for each weld, it is necessary to add the power required to excite the alternator, and the power loss in transmission. For this purpose the resistance was measured of the mains supplying the current to

the primary coil of the welder, and also the resistance of the mains carrying the exciting current; the former was 0.2 ohm, and the latter 2.6 ohms.

The electrical horse-power given in Table I is obtained from the true watts shown by the watt-meter, divided by 746, and the loss in the mains and in the exciting current is got by calculation; the loss in friction is the amount of power required to work engine, alternator and exciter, at no load.

Strength of Welds.—The following particulars are taken from Mr. Fish's draft paper, and, owing to the care with which the work seems to have been done, may be depended upon as correct. He says: "Twenty electric welds, bent hot, were bent through an average angle of 144 degrees before cracking (Table II). In cold bending tests, however, the average with 20 pieces was only 66 degrees before failure of the weld occurred. As a cause for this comparatively early failure, Sir Frederick Bramwell suggests the extreme localization of heat in the electric welding process, and proposes annealing as a remedy. More recently a few welded bars, annealed either in the forge or by reheating a length of 5 inches or 6 inches in the welding machine immediately after the swaging and working of the weld was completed, have been tested by bending cold under the steam hammer. The results were much more favorable than those obtained by Mr. Kirkaldy, the average angle of bend at which failure occurred being about 130 degrees. In testing welds of smaller sizes, the writer has experienced but little difficulty in bending the bars, while cold, round their own diameter; and he suggests that in the Farnley welds failure in the bending tests was hastened by error in the method employed in making and finishing the weld, as well as by any possible effect due to the localization of heat.

"In testing Bessemer steel welds, Professor Kennedy obtained the following results:

Diameter of bar, inches	1.00	0.75	0.50
Average tensile strength of welded bar in percentage of unwelded, per cent	92.	97.5	100.

The decrease in efficiency of weld with increase in diameter, would seem to be due to a proportionately smaller butting press-

ure during the welding. A high percentage of strength at the weld, 80 per cent. or upwards, and probably more than would be required in any practical test of the metal, can be obtained with most of the hardest steels. Most metals that are commercially pure, and certain alloys, weld with little loss of strength, except that which may be due to the annealing effect of the process. This loss may amount possibly to a total of 10 or 15 per cent.

"*Conductivity at Weld.*—Tests made by Professor Sylvanus P. Thompson and others show that the electrical conductivity at the weld is practically the same as that of the unwelded material. This result is possibly an index of the soundness and homogeneity of the electric weld."

Conclusion.—The practical experiments made in the author's works show almost a better conclusion than the tests shown in published tables from the testing machine of the United States Arsenal; for in bending cold here the weld has rarely given way. But in explanation of this it must be borne in mind that all the piecings of plain bars are here more or less swaged. It is well within the mark to state that there is not one out of 500 welds which turns out a failure or even defective.

The question of cost, which, of course, is of importance to commercial engineers, has not been alluded to in detail. The author admits, however, that the payment of royalty, the cost of horse power, and the depreciation, which on electrical apparatus is heavy, together bring the cost considerably over the net cost of the ordinary smith's hearth work, while the actual payments in wages, and so on, are considerably less. The loss in weight of iron is about one-twentieth only. It may be taken that on straightforward welds the total cost will be between 10 and 15 per cent. more than the ordinary smith's work; whereas in delicate work and difficult operations, such as have been alluded to, the cost will probably be one-third of the smith's work. But the real advantage of the apparatus, at any rate as at present arranged, is not so much an economy as a method of securing an absolutely reliable result, and occasionally saving considerable expenditure by its special adaptability.

TABLE I.

POWER EXPENDED IN ELECTRIC WELDING.

Work welded.	May, 1894.	Duration of current.	Electrical horse power.				Indicated horse power.
			Watts / 746	Loss in mains and in exciting.	Loss in friction.	Total.	
		Seconds.	*E.H.P.*	*E.H.P.*	*E.H.P.*	*E.H.P.*	*I.H.P.*
2-inch wrought-iron bar	24	243	59.	10.8	18	87.8	...
" " " polished all over	25	256	55.	10 8	18	83.8	...
" " "	29	255	59.	10.8	18	87.8	88.
$\frac{15}{16}$-inch round iron bar:							
Average of 15 welds	16	57	17.7	6.3	18	42.	42.
" 7 "	25	50	21.	6.3	18	45.3	...
1-inch steam pipe, wrought iron	24	67	20.1	6.8	18	44.9	...
" "	24	66	19.	6.8	18	43.8	...
" "	24	61	24.7	6.8	18	49.5	...
" "	29	86	15.	6.8	18	39.8	49.
" "	29	66½	25.5	6.8	18	50.3	49.
1-inch Bessemer steel shaft	24	64	22.3	8.	18	48.3	...
" "	24	65	22.	8.	18	48.	...
" "	29	62	23.	8.	18	49.	49.
" "	29	54	27.6	7.	18	52.6	51.
$\frac{3}{4}$-inch Bessemer steel	24	37	15.5	6.	18	39.5	36.5
" "	24	38	15.2	6.	18	39.2	36 5
" "	29	50	17.	6.	18	41.	48.
" "	29	54	15.	6.	18	39.	43.
$\frac{1}{2}$-inch Bessemer steel	24	21	9.2	4.7	18	31.9	...
" "	24	21	10.1	4.7	18	32.8	...
" "	24	36	8.	4.7	18	30.7	...
" "	24	22	10.3	4.7	18	34.	...
" "	29	25	9.2	4.7	18	31.9	...
" "	29	30	8.	4.7	18	30.7	34.

Table II.

BENDING TESTS OF ELECTRIC AND HAND-WELDED ROUND 1¼-INCH BARS OF FARNLEY IRON. ELECTRIC WELDS WERE BUTT. HAND WELDS WERE SCARF. EXTRACTED FROM MESSRS. KIRKALDY & SONS' REPORT.

Welding.	Bent cold.			Bent hot.		
	Test number.	Angle of bend.	Effect of bending.	Test Number.	Angle of bend.	Effect of bending.
	Y	*deg.*		*Y*	*deg.*	
Electric Welded	404	37	Broken	444	180	Cracked*
	406	65	Cracked	446	180	Uncracked
	408	65	Broken	448	160	Cracked
	410	34	Cracked	450	175	Cracked
	412	58	Broken	452	94	Cracked
	414	115	Broken	454	180	Uncracked
	416	65	Cracked	456	60	Cracked
	418	57	Cracked	458	180	Uncracked
	420	37	Broken	460	96	Cracked
	422	58	Broken	462	180	Uncracked
	424	58	Cracked	464	180	Cracked†
	426	50	Cracked	466	81	Cracked
	428	90	Cracked	468	163	Cracked
	430	150	Broken	470	98	Cracked
	432	95	Broken	472	180	Cracked
	434	59	Cracked	474	90	Cracked
	436	70	Cracked	476	120	Cracked
	438	35	Cracked	478	180	Uncracked
	440	55	Broken	480	180	Cracked
	442	64	Cracked	482	117	Cracked
	Mean of 20	66	.....	Mean of 20	144	.....
Hand Welded	640	60	Cracked	662	100	Cracked
	642	180	Uncracked	664	75	Cracked
	644	90	Cracked	666	180	Cracked†
	646	150	Cracked	668	180	Cracked†
	648	170	Cracked	670	180	Cracked†
	650	75	Cracked	672	180	Cracked†
	652	180	Cracked	674	180	Cracked†
	654	180	Uncracked	676	90	Cracked
	656	180	Cracked	678	180	Cracked†
	658	180	Cracked	680	180	Uncracked
	660	70	Cracked	682	95	Cracked
	Mean of 11	138	.....	Mean of 11	147	.....

* Very slightly cracked. † Slightly cracked.

NOTES.

TESTS OF SERVE TUBES.

"Engineering" gives an account of some experiments recently made by Mr. Blechynden, of the Barrow Shipbuilding Company, to determine the relative efficiency of Serve and plain tubes in transmitting heat. The apparatus used consisted of a set of three model boilers, placed back to back, each traversed by a plain and a Serve tube. The boilers were $7\frac{1}{2}$ inches in diameter and 21 inches long, and were clothed with asbestos and cotton wool. The Serve tubes were $2\frac{1}{2}$ inches in diameter outside and $2\frac{3}{16}$ inches inside, and had seven ribs $\frac{7}{16}$ inch deep by $\frac{3}{32}$ inch mean thickness. The plain tubes were of iron, $2\frac{3}{8}$ inches in diameter outside, and 2 inches inside. The tubes of one boiler were coupled to those of the next one in line, and Siemens' pyrometers fitted at each end of each tube. The experiment consisted in causing a blow-pipe gas jet to send its flame through each set of tubes separately, noting the pyrometer temperature, and also the evaporation effected. The mean of several experiments showed that with a temperature of 1,000 degrees Fahrenheit at the blow pipe end of the boilers, and 500 degrees Fahrenheit at the uptake ends, the Serve tube transmitted 6,000 British thermal units per square foot per hour, and the plain tubes 4,500 British thermal units per square foot per hour. The area measurements were made on the outside or emission surfaces of the tubes.

STEAM PIPE EXPLOSION ON THE *ARÉTHUSE*.

While undergoing a trial of her machinery preparatory to sailing for Madagascar, a steam pipe exploded on board the French cruiser *Aréthuse*, resulting in the instant death of six men and the serious injury of six others. According to the account published in "Le Yacht," the vessel had been under

way but a short while, the engines making about 30 revolutions, and the steam gauges indicating about 57 pounds, when a violent explosion was heard in the fire room. Streams of water were at once turned into the fire room in order to condense the steam as rapidly as possible, and as soon as it was possible to enter the room six men, charred almost beyond recognition, were found stretched upon the floor, and six others more or less seriously injured. No explanation is given of the cause of the explosion. The *Aréthuse* has eight boilers, four on each side of a fore and-aft fire room.

AN ALUMINUM TORPEDO BOAT.

[From "Engineering" and "The Engineer."]

Messrs. Yarrow and Co. recently completed a second-class torpedo boat for the French government, the hull and fittings of which are almost entirely of aluminum. She is 60 feet long, 9 feet 3 inches beam, and when ready for trial, carrying a load of three tons, weighed 9.5 tons.

As boats of this type are intended to be carried on the deck of large men-of-war, to be lowered in the water and to act, when necessity requires, as a scout to watch the movements of the enemy's torpedo boats, or for the use of the ship for landing and embarking the officers, it is self-evident that lightness of construction is of paramount importance, not only because reduced displacement secures increased speed, but, considering that the boat has to be lifted and lowered by the tackle available on board the ironclad or other vessel, it is clear that the weight to be handled should be reduced to the minimum. Moreover, as these boats are placed high up on a ship's deck, any reduction of top weight increases the stability of the ship to which they are attached. In the English navy a large number of these second-class torpedo boats is used to form part of the standard equipment of all ironclads. The French naval authorities, however, up till last year had not adopted them, and as they were desirous of introducing them into their navy, they invited tenders for the best torpedo boat of this class which modern improvements enabled constructors to build, to serve as a

type to be followed in the future. The primary conditions imposed were good sea-going qualities and lightness, combined with the highest obtainable speed. The proposal submitted by Messrs. Yarrow and Co. was the one accepted, as they were prepared to guarantee a higher speed and lighter weight to be lifted than any other firm, mainly in consequence of having determined to adopt aluminum for the construction of the hull.

It is hardly necessary to say that the pure metal has not been used, "certain alloys," among them 6 per cent. of copper, having been introduced to give greater strength and stiffness to the material. The stem and stern frames are of galvanized steel, and the chimney is also of steel, though the outer casing to it is of aluminum. The deck plates over the boiler space are likewise of steel, it being considered unwise to subject aluminum to the danger from distortion that might arise through heat. In the case of the outer funnel there is not the same fear, as the cylindrical form is not likely to change.

In regard to the scantling, in most parts there is an addition of about 25 per cent. in the thickness of the material, and in general construction the boat appears to be somewhat on the usual lines of a steel vessel of this type, excepting that reverse frames are more freely introduced. The appearance of the structure is certainly more comfortably substantial than in the case of steel vessels. In spite of this, the lower specific gravity of the aluminum enables the hull to be reduced by about 50 per cent. from the weight that would be necessary were steel used. In the case of the boat in question, the weight of hull is about 2 tons, the total weight, as tested when the vessel was lifted, being 9½ tons, three of which were chargeable to the boiler.

The aluminum alloy used has a tensile strength of 14 tons to the square inch, and, compared to steel, has a higher elastic limit in terms of its tensile strength; this, of course, being a point of great advantage in the construction of small craft of this nature. The plates, angles, etc., have all been worked cold, and no insurmountable difficulty was found in carrying out the operations. The boat is built in the usual way, and triple riveted with aluminum rivets. The keel plates are .108 inch thick, and the other

hull plating from .069 to .098 inch, while the deck is of .079 inch plates. The six bulkheads in the boat are also of aluminum.

Although aluminum is not attacked by sea water in the same manner as steel, in regard to rusting or corrosion, it has a disadvantage in the fact that it cannot be used in positions where it is likely to be subjected to heat, under the action of which it will soon lose its strength, while it fuses at a comparatively low heat. In the construction of the boat no plates or angles were touched by the fire; everything was bent cold. Alkali also affects it disadvantageously, and for this reason it would not be advisable to wash out condensers or other parts with soda, unless great care were taken that none ran into the bilge or in any other way came in contact with the hull structure. These appear to be the two chief drawbacks to the use of the metal, supposing one is prepared to pay the price it costs. This, of course, is the crucial point, and to judge from Messrs. Yarrow's experience, there does not seem much probability that the new metal will be largely used for shipbuilding purposes, for many years to come at any rate. Mr. Yarrow said that the aluminum cost from 3s. to 5s. per pound, the former price doubtless referring to plates and angles. The cost of the aluminum in this boat, which was all imported from France, is stated to have been about £1,000. Against this increased cost there is a saving of about two tons in weight, and a gain of about 3½ knots in speed over vessels of the same class and dimensions in the British navy, which steam under the like conditions at 17 knots.

During all the trials of this boat, the absence of vibration and of noise in the engine room has been most noteworthy. On the 30th of September, she was run at various speeds from dead slow up to the highest attainable, and at none was the slightest vibration to be felt in any part of the boat, forward, aft or amidships. The only thing of the kind perceptible was a species of purring thrill. Part of this is no doubt due to the construction of the engines; but much remains to be explained by the metal. Although aluminum is in some forms one of the most sonorous in existence, in the shape of a torpedo boat, it is wanting in that resilience and vibratory stiffness peculiar to steel. This largely

explains the comparative silence of the engines. In a thin steel hull every sound is magnified, in the aluminum boat it is deadened—the new metal behaving apparently very much like wood.

Although the use of aluminum has been confined almost wholly to the hull and fittings, some little has been used about the engines, the propeller being of aluminum bronze.

The engines of this boat are of the triple-expansion type, and work up to about 600 revolutions when running at full speed, the I.H.P. being about 300. Steam is furnished by a water-tube boiler of the Yarrow type, having 500 square feet of heating surface.

The official trial took place on the 20th of September, the French Government being represented by a Commission, of which Captain LeClerc was the president. It consisted of a continuous run of two hours' duration in the estuary of the Thames. Weather calm; number of persons on board, seventeen; total load on trial, three tons.

RUNS ON THE MILE.

No. of run.	Steam in boiler.	First receiver.	Second receiver.	Vacuum in condenser.	Air pressure in stokehold.	Revolutions per minute.	Speed.	First means.	Second means.	Mean of means.
				in.	*in.*					*Knots.*
1.....	185	72	12	24	2½	600.36	22.222			
								20.893		
2.....	185	72	12	24	1⅓	598 80	19 565		20.807	
								20.721		
3.....	175	72	12	24	2⅛	593 40	21 877		20.566	
								20.412		20.503
4.....	175	62	11½	24	1½	578 16	18.947		20.299	
								20.187		
5.....	180	65	11	24	1½	586 80	21 428		20.341	
								20 496		
6.....	185	70	12¼	24	1¾	591.48	19.565			

During the trial of two hours' duration the engines made 70,948 revolutions, being at the rate of 591.2 revolutions per minute, corresponding to a mean speed during the entire run of 20.558 knots per hour. The boiler made ample steam without

priming, and the engines worked without any heating. The vibration was very slight, and not appreciable.

THORNYCROFT'S AUTOMATIC FEED REGULATOR.

Mr. J. I. Thornycroft, the torpedo-boat builder, has recently brought out an automatic feed-water regulator, which has been so satisfactory on the boilers of the *Daring* and the *Decoy* of the English navy that it has also been fitted to the boilers of the *Speedy*. Unlike other feed regulators, all parts of this one are contained within the boiler, thus getting rid of friction in stuffing boxes, etc. The apparatus consists of a float placed in the upper drum of the boiler, and connected with a valve fitted to the internal feed pipe. Provision is made for adjusting the gear from the outside of the drum through a hand hole in the end of the latter.

THE ATLANTIC RECORD.

On the 31st of August the *Campania* made the fastest eastward passage on record, making the run from Sandy Hook Lightship to Daunt's Rock in 5 days 10 hours and 47 minutes, lowering the best previous record, also her own, by 1 hour and 20 minutes. The distance run was 2,814 miles, and the mean speed 21.51 knots per hour. About the same time, the *Lucania* broke the westward record, which also was the *Campania's*, making the run from Daunt's Rock to Sandy Hook Lightship in 5 days 8 hours and 38 minutes, which was 51 minutes faster than the *Campania's* time. On her return trip, she made the run in precisely the same time, 5 days 8 hours and 38 minutes, an unprecedented performance for an eastward run, and lowered this record 2 hours and 9 minutes. On her next trip westward, which was completed on the 28th of September, she again lowered the record, this time making the run in 5 days 7 hours and 48 minutes. The time for the passage was again lowered by the *Lucania* in the early part of November, when she made it in 5 days 7 hours and 23 minutes.

The following summary of these four voyages shows how the *Lucania* has reduced the record:

Direction.	Time.	Distance.	Best day's run.	Mean speed.
	h. *m.* *s.*			
Westward	5 8 38	2,787	555	21.65
Eastward	5 8 38	2,810	...	21.84
Westward	5 7 48	2,782	552	21.77
Westward	5 7 23	2,779	549	21.81

While the *Lucania* was thus reducing the time between Queenstown and Sandy Hook, the *New York*, of the American Line, twice during September reduced the record between the Needles and Sandy Hook Lightship. On the first voyage, the time was 6 days 8 hours and 38 minutes, and the distance run 3,050 miles, corresponding to a speed of 20 knots an hour. The second one was made in 6 days 7 hours and 14 minutes, at the rate of 20.15 knots an hour, the distance run being 3,047 miles.

SHIPS.

UNITED STATES.

Maine.—The official trial of this armored cruiser took place in Long Island Sound on Wednesday, October 17, 1894. It was of four hours' duration, and was a trial of the machinery alone, the hull having been built by the Government, and the machinery by N. F. Palmer, Jr., & Co. (Quintard Iron Works), New York. The contract required that 9,000 I.H.P. should be developed by the main engines and the air and circulating-pump engines, as the mean of four hours' continuous steaming.

As a full description of the ship and of her machinery will be given in the next number of the JOURNAL, only the result of the official trial will be given here.

The *Maine* is 318 feet long on the water line, 57 feet beam, and displaces 6,648 tons on a mean draught of 21 feet 6 inches. Her trial was made at a mean draught of 18 feet 6 inches, the displacement being 5,500 tons.

Her engines are vertical, with cylinders 35½, 57 and 88 inches diameter, and 36 inches stroke.

The following are the data of the trial:

	Starboard.		*Port.*
Steam pressure at boilers		144.	
engine	136.3		134.6
in first receiver, absolute	67.7		66.6
in second receiver, absolute	28.8		34.3
Vacuum	23.88		22.84
Mean effective pressure in H.P. cylinder	54.37		53.66
I.P. cylinder	20.91		19.60
L.P. cylinder	16.24		16.27
equivalent referred to L.P. cylinder	33.72		33.08
Revolutions of main engines per minute	125.96		122.31
Double strokes per minute of combined air and circulating pumps	25.77		21.22
Revolutions of fire-room blowers		450.	

	Starboard.		*Port.*
Air pressure in main duct (ash pit draft) in inches of water		1.97	
Indicated horse power, H.P. cylinder	1,216.89		1,165.56
I.P. cylinder	1,218.35		1,108.94
L.P. cylinder	2,261.71		2,200.
aggregate, each engine	4,696.95		4,474 50
collective, both engines		9,171.45	
air and circulating engines	28.25		24.59
main engines, air and circulating pumps		9,224.29	
all machinery in operation		9,292.65	

Inasmuch as the trial was for the purpose of determining the I.H.P., no attempt was made to accurately measure the speed, but the patent log showed a mean of 17.45 knots for the four hours.

The machinery worked faultlessly, and the general opinion of those who witnessed the trial is that the maximum power which can be maintained for four hours was not developed on this trial.

Ericsson.—The contractors for the construction of this torpedo boat having determined to make a run over the trial course in Long Island Sound, advantage was taken of it to indicate the engines at various speeds, in order to construct a curve of revolutions and indicated horse power. The course was 25 nautical miles in length, and was divided into nine subdivisions, eight of them three miles long, and the ninth, one mile, and their limits marked by buoys. The revolutions between the first and second buoys were regulated for 200 per minute, and were gradually increased between each succeeding odd and even numbered buoy, the speed being adjusted between the even and odd numbered ones. Returning over the course, the reverse process was followed, the speed being regulated between the odd and even numbered buoys, and the distance between the even and odd numbers run at a uniform speed. Indicator diagrams were taken for each speed, the result being as follows:

	Revolutions.		I.H.P.			Speed.
	Starboard.	Port.	Starboard.	Port.	Total.	
1	194.7	192.1	130.53	117 66	248.19	10 67
2	250.1	239 8	242.53	187.29	429.82	14.56
3	281.1	277.3	369.00	344 58	713.58	17.37
4	314.0	309 8	528 47	482.82	1,011.29	17.87
5	396 5	396 5	945.52	934.23	1,879.75	20.69
6	361.5	369.0	736.41	821 27	1,557 68	22.36
7	357.2	360.1	710.54	728.06	1,438 60	22.32
8	316.5	319.5	518.97	518.12	1,037.09	21.07
9	254.1	251.2	265.74	244.84	510 58	16.56
10	200.5	193.0	149.74	126.69	276.43	13.15

Runs 1 to 5, inclusive, were made against the tide, and runs 6 to 10, inclusive, with the tide. Subsequent examination indicated that some of the buoys, which had been placed some time previously, were not in position, so that the speed given cannot be relied upon as being correct. Furthermore, the strength of the tide was not known.

Run No. 6 was intended to be run at the same speed as No. 5, but, through a misunderstanding on the part of the men in one of the fire rooms, the door of that room was opened, releasing the pressure and causing a drop of 50 pounds in the steam pressure.

After completing the return run over the course, another run was made over the three miles between the first and second buoys, this time at full power. The revolutions per minute for this run were 385.8 and 384.2 for the starboard and port engines respectively, the I.H.P. 1,826.13, and the speed, against the tide, 20.11 knots. The return run was not made on account of a joint blowing out on the check valve of one of the boilers.

The mean draught of water for the trial was 4 feet 10½ inches, corresponding to a displacement of about 126 tons.

The *Ericsson* is 150 feet long on the water line, 15 feet 6 inches beam, and on a mean draught of 4 feet 9 inches, has a displacement of 120 tons. Her bunker capacity is 40 tons. She has one fixed torpedo tube in the bow, and two training tubes on

deck, all being for 18-inch torpedoes, besides which she mounts four 1-pounder rapid fire guns.

Her machinery consists of twin-screw, quadruple-expansion engines, steam for which is furnished by two Thornycroft boilers working under a pressure of 250 pounds per square inch. The engines were designed for 1,800 I.H.P. at full power. Both are in the same compartment, and each has cylinders 11½, 16, 21½ and 30 inches diameter by 16 inches stroke. The steam valves are of the piston type, except for the low pressure cylinders, where double-ported slides have been fitted. The engine framing consists of forged steel columns and stays, and the bed plate of plate steel.

There is one condenser for both engines; it contains 1,379 square feet of cooling surface. The air pumps, one for each engine, are single acting, inclined bucket and plunger pumps, worked by eccentrics from the engine shaft. The diameter of the bucket is 14 inches and its stroke 3 inches. The circulating pump is of the centrifugal type, with a runner 14¾ inches in diameter.

The boilers, of the well-known Thornycroft type, one forward and the other abaft the engines, contain 85 square feet of grate and 4,698 of heating surface. The screws are of manganese bronze, 4 feet 9 inches in diameter and 7 feet 8 inches pitch, each with 8.5 square feet of helicoidal area.

One of her preliminary trials was interrupted by the breaking of an eccentric strap on the port engine, and the first attempt at an official trial, November 12, by the breaking of another on the starboard engine. The second attempt at an official trial was stopped on account of fog, and the next one by the carrying away of two studs for the delivery valves of one of the air pumps.

Torpedo Boats Nos. 3, 4 and *5*.—The design for these boats, which were authorized at the last session of Congress, has been completed, and proposals for their construction will soon be issued. While the general design of the hull of the *Ericsson* has been followed as regards scantlings, spacing of frames, fittings, etc., there are many points of difference between the new boats and the *Ericsson*, the principal ones being the cutting away of

the keel from the midship section to the water line at the stern, so that the rudder is placed between the shafts of the two engines, and the placing of the officers' quarters forward, the latter being comparatively roomy on account of the torpedoes and tubes being carried on deck.

The principal data of the new boats are:

Length on L.W.L., feet	160.
Beam at L.W.L., feet	16.
Draught, forward, feet	5.
amidships, feet	5.
aft, feet	5.
Displacement, tons	135.
Capacity of coal bunkers, tons	45.
I.H.P.	2,000.
Speed	24.5

The weights carried on the displacement of 135 tons, are: Torpedo guns, torpedoes, rapid-fire guns and ammunition, 5.5 tons; coal, 9 tons; crew, boat, anchors and equipment, 7 tons. The remainder is made up of hull and machinery, the latter contributing 60 tons.

The hull is divided into thirteen water-tight compartments; the first one being small and intended as a collision compartment; the second contains the capstan engine and stores, the third the captain's room, the fourth the ward room, the fifth officers' quarters, the sixth and ninth the boilers, the seventh and eighth the engines, the tenth the galley, the eleventh quarters for four machinists, with a magazine at the after end in the center of the boat; the twelfth is given up to berthing and messing the crew, and the thirteenth is the tiller room.

There are two conning towers, one forward over the ward room, and the other aft, over the machinists' quarters, about 30 feet from the bow and stern respectively. There is a steering wheel in each tower, the forward one connecting with the steering engine, which is placed immediately beneath the floor.

Unlike the usual type of torpedo boats, these boats will not have tubes fixed in the bow, but instead carry three tubes mounted on carriages on deck, each capable of being trained

through a considerable arc. The torpedoes, of which there are four, are also stowed on deck. Besides the torpedoes there are three 1-pounder rapid-fire guns, for which 1,800 rounds of ammunition will be provided.

The complement will be four commissioned officers, four machinists, and twelve men.

Another feature of these boats is that, although they have twin-screw engines, which, in torpedo boats, are usually placed side by side in the same water-tight compartment, each engine, together with its auxiliary machinery, has been placed in a separate compartment, one forward of the other. The object of this is to give the boats a greater chance for escape in case of injury to the engines by shot. If placed in the same compartment, one well-directed shot might disable both engines, but placed as these are the chance of total disablement is reduced. On account of this arrangement of machinery necessitating slightly more space than it would if placed in one larger compartment, the engines have been made triple instead of quadruple-expansion, as in the *Cushing* and *Ericsson*, and each engine is absolutely independent of the other.

The actual space occupied is, however, very little more than that in the *Ericsson*, where the machinery takes up 61.5 feet in the length of the boat; here the figure is 64.5, only three feet more, although the I.H.P. is 2,000 against 1,800 in the *Ericsson*.

There is a water-tight door in the bulkhead between the two engine rooms, and the starting and reversing gear for each engine is near this door, thus making it possible for one man to handle both engines when working under the usual conditions.

The piston and connecting rods have been made hollow in order to reduce the vibration due to inertia of the moving parts, and four cylinders have been adopted instead of three in order to get a better running balance.

The high-pressure and intermediate, as well as the two low-pressure cranks are placed opposite to each other, each pair being at right angles to the other pair. The cylinders are as close together as possible consistent with keeping them in the same vertical plane. This is done to prevent the vibration due to

couples formed by one piston going up while the other is coming down. These couples often cause the most serious vibrations, especially if the engines happen to be placed at the node points of the hull's vibration.

Triple-expansion engines were adopted instead of quadruple ones chiefly for the sake of lightness and compactness, and to avoid the large low pressure cylinder which would be required if only four cylinders were used. The adoption of a quadruple expansion engine might have resulted in a slight increase of economy, but in the absence of experimental data, it is not believed that this gain would have warranted sacrificing the manifest advantages of the triple-expansion engine. A quadruple-expansion engine with two low pressure cylinders would require five cylinders instead of four, as in the design adopted. Inertia curves were constructed, and it was found that less vibration would actually be produced by the four cylinders than by five when the cranks were placed at satisfactory angles in each case. The high and intermediate pressure cylinders are both made in one casting, while the two low pressure cylinders form another casting, the two being firmly bolted together and practically forming a bed plate for resisting vertical strains.

The real bed plate is a plate of steel $\frac{3}{8}$-inch thick, upon which the cast-steel crank-shaft pillow blocks are bolted. The holding-down bolts pass through the pillow blocks, the bed plate and ship's frames (which are properly spaced for this purpose), thus making the engine bed plate and the hull one continuous structure. The frames are braced only in an athwartship plane, but blank places are left to secure fore-and-aft braces should they be found necessary.

The valves have been placed upon the sides of the cylinders, and so arranged as to make as short and direct passages as possible. They are all of the piston type, one for the H.P. cylinder and two for each of the others. The valves are worked from a separate valve shaft driven by gearing from the main crank shaft, and the engines reversed by a movable sleeve so arranged with spiral feathers and grooves that a rotary motion is imparted to the valve shaft when the sleeve is moved fore and aft.

The blowers, which discharge into air-tight fire rooms, are driven by compound engines, the cylinders of which are placed opposite. Their moving parts will be of equal weight and work on opposite cranks. These engines, as well as all the other auxiliaries, will exhaust into the low pressure receivers. This practically converts the compound blower engines into triple-expansion ones.

To lower the temperature of the fire room and make it more comfortable, a door will be fitted in the back end of the ashpan in addition to the one usually fitted in front. The front door can be closed whenever desired and the back one opened. This will cause all the air to pass over and around the boiler before entering the ashpit, thus sweeping all the heat into the furnace, instead of allowing it to radiate into the fire room.

The type of boiler has not been decided upon further than that it will be of the coil or tubulous variety. Ample weight has been allowed to provide good durable boilers of this type. There will be two of them, each in a separate water-tight compartment, one forward of the forward engine, and the other abaft the after engine. The total grate surface will be about 94 square feet, and the heating surface about 5,120, and the working pressure 250 pounds.

Each condenser will have about 800 square feet of cooling surface. The air pumps will be similar to those of the *Ericsson*, and be worked from an eccentric on the engine shaft.

ARGENTINE REPUBLIC.

Patria.—A short description of this torpedo gunboat was given on page 176 of the current volume of the JOURNAL, but more complete data are now at hand, as well as the record of the trials. In appearance she resembles somewhat the later torpedo gunboats of the English navy, except that she has a complete spar deck, the poop and forecastle decks having been continued the entire length of the vessel. The engines are of the vertical triple-expansion type, each in a separate water-tight compartment, and capable of developing, collectively, about 4,500 I.H.P. The boilers are of the locomotive type, four in number, and are in two compartments.

She has fifteen water-tight compartments, and bunker space for 250 tons of coal, though only one-half of this amount was carried on her official trial.

Her battery comprises two 4.7-inch, four 8-pounders, two 3-pounders, two 1-pounders and five 18-inch torpedo tubes.

Her dimensions are as follows:

Length between perpendiculars, feet	250
Breadth, feet	31
Depth, feet	16
Draught, mean, feet	10
Displacement, with 125 tons of coal, tons	1,070

Her first trials were made in Liverpool Bay during heavy weather, when, for eight hours, under natural draft, she made 17.6 knots with 201 revolutions of her engines; during this trial, six runs were made over a base 8.1 miles long at the rate of 17.915 knots. For her forced-draft trial, she was steamed to the Clyde, where she made six runs over the measured mile at the rate of 20.575 knots on 233.5 revolutions, and 20.56 knots for three hours on 233.4 revolutions. She also made several runs over the mile using natural draft, when the speed was 17.772 knots with 190 revolutions, equivalent to about a knot more than she made in Liverpool Bay for the same revolutions. Her contract was for a speed of 19.5 knots.

DENMARK.

Heimdal.—A sister vessel to the *Geiser*, described in Volume V of the JOURNAL, has been launched at Copenhagen. She is 257.5 feet long, 27.5 feet beam, about 12 feet draught, and of 1,270 tons displacement, and has a protective deck 1½ inches thick. Her engines are of 3,000 I.H.P., and are expected to give her a speed of 17 knots. The cylinders are 19, 30 and 50 inches diameter by 18 inches stroke. Her battery comprises two 4.7-inch, four 12-pounders, six machine guns und four torpedoes.

ENGLAND.

Monarch.—This old turret ship has recently undergone a remodeling, all her spars and rigging having been removed and three military masts substituted, new triple-expansion engines

and high pressure boilers fitted in place of the old simple engines and low pressure boilers, and water-tight bulkheads fitted to reduce the size of many of her compartments.

She is a single-screw vessel, of iron, and was built upwards of twenty-five years ago. She is 330 feet long, 57.5 feet beam, and when fully equipped draws 25 feet of water, at which her displacement is 8,320 tons. Her side armor is only from 6 to 7 inches thick, and that on her turrets from 8 to 10 inches.

The new engines, which were constructed by Messrs. Maudsley, Sons & Field, were designed for 6,500 I.H.P. with natural draft, and 8,000 with ½ inch water pressure, and are of the usual vertical triple-expansion type, the cylinders being 49, 74 and 112 inches in diameter and the stroke 51 inches. A piston valve is fitted for the high pressure cylinder, and double-ported slides for the intermediate and low pressure. The bed plate is of cast iron, and the columns of forged steel, four for each cylinder. There is one main condenser containing 10,000 square feet of cooling surface, and an auxiliary condenser with 1,500 square feet. For the main condenser, there are two air pumps each 27 inches in diameter, with a stroke of 25½ inches, one worked from the high and the other from the low pressure crosshead. There are two main circulating pumps of the centrifugal type, with runners 48 inches in diameter. The screw propeller is two-bladed.

There are eight single-ended boilers 15 feet 4 inches in diameter and 10 feet long, each with eight corrugated furnaces 41 inches mean diameter. The grates are 5 feet 9½ inches long, and the total grate surface 632 square feet; the heating surface is 18,890 square feet. There is but one smoke pipe. For supplying air to the furnaces, there are eight double inlet fans 72 inches in diameter, and for ventilating purposes four of the same size.

Besides the auxiliary machinery mentioned, she is provided with an electric light plant, evaporators and distillers, and steam steering gear. The weight of the new machinery is 1,100 tons.

Her armament consists of two 12-inch, two 9-inch, and one 7-inch M.L.R., and fourteen rapid fire guns.

Her natural-draft trial took place on the 16th of October, and the forced-draft trial on the 18th, the result being—

	Natural draft.	*Forced draft.*
Draught of water forward, feet and inches	21–10	21–6
Draught of water aft, feet and inches	25–6	25–5
Steam pressure in boiler, pounds	148.2	152.6
Air pressure, inch	...	.6
Mean revolutions of fan	...	240
Vacuum in condensers, inches	28.03	27.28
Revolutions per minute	82.47	86.56
Mean pressure in cylinders:		
High pressure	60.8	69.6
Intermediate pressure	25.2	29.42
Low pressure	9.95	11.24
Mean pressure in receivers:		
Intermediate pressure, pounds	41.7	43.6
Low pressure, pounds	6.8	8.3
Indicated horse power:		
High pressure cylinder	2,435.45	2,925.80
Intermediate pressure cylinder	2,302.79	2,820.90
Low pressure cylinder	2,083.64	2,469.59
Total	6,821.88	8,216.29
Speed of ship by log, knots	13.3	14

The old engines had two horizontal cylinders, 120 inches in diameter and 54 inches stroke, and developed 7,840 I.H.P.

Fox.—A second-class sheathed cruiser of the *Astrea* class, built and engined at Portsmouth dockyard, and similar to the *Flora* and *Charybdis*, described on page 605 of the last number of the JOURNAL, has completed her trials with natural and with forced draft. The following are the mean results:

	Natural draft.	*Forced draft.*
Date of trial	Sept. 28.	Oct. 16.
Mean draught of water, feet	18.25	18.
Steam pressure, pounds	143.	144.8
Air pressure, inches	0.3	1.3
Vacuum, inches	25.5	25.2
Revolutions	130.	140.8
I.H.P.	7,034	9,063
Speed by patent log	19.	19.9

The vessels of this class all have triple-expansion engines, with cylinders 33, 49 and 74 inches diameter by 39 inches stroke, designed to work with a boiler pressure of 150 pounds.

The screws are 13 feet diameter and 17 feet pitch. There are eight single-ended boilers 13 feet 2 inches in diameter and 9 feet 7 inches long, containing 600 square feet of grate and 15,655 of heating surface.

The *Fox* is 320 feet long, 49.5 feet beam and 19 feet draught, with a displacement of 4,360 tons.

The armament comprises two 6 inch, eight 4.7-inch, and nine smaller rapid fire guns.

Bonaventure.—Another second-class cruiser has had satisfactory trials under natural and forced draft. The results were:

	Natural draft.	*Forced draft.*
Steam pressure	149.	146.
Air pressure	0.44	0.8
Vacuum	26.8	26.3
Revolutions	133.	143.2
I.H.P.	7,340.	9,279.
Speed by patent log	19.2	20.

The machinery, which was supplied by the Fairfield Company, is similar to that of the *Fox*. Her boilers have 553 square feet of grate and 15,600 of heating surface.

Harrier.—This torpedo gunboat, which was described on page 426, has completed her trials with the following results:

	Natural draft.	*Forced draft.*
Duration of trial, hours	8.	3.
Steam pressure, pounds	150.	149.
Air pressure, inches	0.84	1.77
Vacuum, inches	26.9	27.3
Revolutions	228.8	253 9
I.H.P.	2,696.	3,592.
Speed by patent log, knots	18.	19.

The boilers of one of the vessels of this class have recently been illustrated, and from the data there shown the following is taken. They are four in number, and of the wet-bottom locomotive type, each with two furnaces.

Length of boilers over heads, feet	15.75
over tube sheets, feet	7.125
Diameter of barrel, feet	7.75
Width at fire-box end at top, feet	7.83
near bottom, feet	8.50

Height at fire-box end, feet	8.125
Tubes, number of stay	88
plain	336
diameter, inches	2
Spaced in diagonal rows, making an angle of 30 degrees with the horizontal.	
Height of furnace, feet	4.9
Water space on sides and bottom, inches	4.5

Sharpshooter.—This torpedo gunboat has had a number of trials recently preparatory to being placed in commission for service with the Channel Squadron, but after each one some defect either with her boilers or engines has necessitated a delay. Her last trial was to have been of thirty hours duration, but was curtailed on account of hot crank-pin brasses. The power maintained was 2,500 I.H.P. Since joining the squadron, the report from her is to the effect that her coal consumption is large.

Fleet Cruisers.—It is authoritatively stated that the English Government will next year build two fast cruisers or dispatch vessels, intended also to act as scouts for a fleet. They are, of course, to be designed by Mr. W. H. White, and will be about 270 feet long, 40 feet beam, 16 feet mean draught, of about 2,400 tons displacement, and have a battery of 4.7-inch guns. They will have engines of 10,000 I.H.P., and are expected to make a speed of 22 knots. Their bunker capacity will be 500 tons.

Decoy.—Another torpedo-boat destroyer, sister to the *Daring*, described on page 605, has completed her trials, making 27.641 knots on the measured mile, and 27.77 as a mean of three hours' steaming, with 3,900 indicated horse power. Her mean draught was 6 feet 3 inches, and the displacement 240 tons.

The engines and boilers are of the same type as those of the *Daring*. A feature of the engines which was not mentioned in the description of the *Daring* is that the cranks of the two adjacent cylinders are not directly opposite each other, but are at an angle equal to the supplement of the angle between the axes of the cylinders. The two condensers contain 4,400 square feet of cooling surface. The air pumps are 16¾ inches diameter and 5½ inches stroke.

Lynx.—A torpedo-boat destroyer, similar in all respects to the *Ferret*, described on page 613, and constructed by Laird Bros.,

started her trials on the Clyde on the 23d of August; but after running for half an hour a small steam pipe connected with the evaporator burst, and the trial was postponed. A satisfactory trial was subsequently made, the mean speed on the measured mile being 27.15 knots, and that for the three hours 27.01 knots, one one-hundredth of a knot in excess of the guarantee.

The subdivision and general arrangement of this boat are similar to the *Hornet*, built by Yarrow; and, like the *Hornet*, she has four smoke pipes, one for each of the Normand boilers. Her bunkers have a capacity of 70 tons.

Rocket.—Another vessel of this class, built by J. and G. Thomson, Clydebank, was launched on the 14th of August. She is similar in all general features to the *Hornet*, and, like the *Lynx* and *Ferret*, has Normand boilers. On a preliminary trial on the Clyde she is said to have made 28¼ knots, but the draught of water was not given, nor was it stated whether she had on board the 30 tons of coal which these boats are required to carry.

Torpedo Boats Nos. 94 and *95.*—These two first-class boats, built by Mr. J. S. White, of East Cowes, are similar to those described on page 615. On their trials, which were recently completed, *No. 94* made 23.257 knots, and *No. 95*, 23.21, the contract being for 23 knots.

FRANCE.

Descartes.—This sheathed cruiser was launched from the Chantiers de la Loire on the 27th of September. She is of the following dimensions:

Length between perpendiculars, feet	315.95
Breadth, extreme, feet	42.32
Draught, mean, feet	19.72
Displacement, tons	3,937.

Her machinery consists of twin-screw vertical triple-expansion engines of 7,890 I.H.P., steam for which is to be furnished by sixteen Belleville boilers working at a pressure of 240 pounds.

Her battery comprises four 16-cm., ten 10-cm., fourteen 47-mm., and eight 37-mm. rapid fire guns, and four torpedo tubes.

Jemmapes.—The trials of this battleship, under forced draft,

gave a mean speed of 16.7 knots on 9,123 horse power. She is 284 feet long, 57.4 feet beam, 22 feet mean draught, has a displacement of 6,487 tons, and mounts two 34-cm., and four 10-cm., and fourteen smaller caliber rapid-fire guns.

Brennus.—This battleship has just been completed, and is now preparing for her official trials, having made 15.7 knots on a preliminary run. As designed her dimensions are:

Length between perpendiculars, feet	360.9
over all, feet	374.8
Breadth, extreme, feet	67.0
Depth to under side of battery deck, feet	41.
Draught, mean, feet	26.25
Displacement, tons	10,907.
Capacity of coal bunkers, tons	550.

Upon completion, it has been discovered that her displacement will be fully 400 tons greater than it was expected to be, and this increase is attributed to the fact that she has been under construction so long that many small changes have from time to time been made in the design, all of which have added a considerable amount to the displacement.

She has an armor belt 15¾ inches thick, with 16 inches of armor on the turrets, of which there are two, one forward with two 12-inch guns in it, and the other aft with one 12-inch. Besides these heavy guns, she carries ten 6.3-inch guns, and twenty machine guns, the former protected by 4 inches of armor.

Her twin-screw engines are of the triple-expansion type, and have been designed for 13,000 I.H.P. The boilers are of the Belleville type.

D'Iberville.—A torpedo gunboat or scout, built at St. Nazaire, from the design of M. de Bussey, has completed her trials with satisfactory results. The contract for her construction required that her speed should be not less than 21.5 knots, without exceeding a coal consumption of 32.7 pounds per square foot of grate, that her bunkers should hold enough coal for 6,000 miles at 10 knots, that she should carry on trial enough for 4,500 miles, and that her displacement should not exceed 935 tons.

The following are her dimensions:

Length between perpendiculars, feet	262.4
Breadth at the water line, feet	26.5
Depth amidships, feet	17.42
Draught, normal, mean, feet	10.27
Displacement, normal, tons	910.4

She has two vertical triple-expansion engines, each with four cylinders 22, 33.8 and 36.2 (two) inches in diameter and 19 inches stroke, which were designed for 5,000 I.H.P. with a piston speed of 920 feet per minute. Her boilers are of the Lagrafel-d'Allest type, four in number, and contain 339 square feet of grate, and 11,365 square feet of heating surface. Her screws are 6.66 feet in diameter and have a pitch of 8.65 feet.

The following are the results of her official trials:

Duration of trial, hours	6	18	6	4.27
Revolutions per minute	207.6	258.	280.	292 3
I.H.P	1,775.	3,267.	4,340.	4,931.
Speed, knots	15.82	19.3	20.7	21.61

She was brought to her normal draught for each of the above trials. The second and third trials formed a continuous run of 24 hours. She had been out of dock for two months before the final trial was made, and the condition of the sea at the time was not favorable for high speed, so that "Le Yacht," from which this account is taken, thinks that under favorable conditions she can make one-quarter knot more.

Friant.—A cruiser of the second-class has had her preliminary trial, having made 17.5 knots for ten hours on 6,000 I.H.P. She is 308 feet long, 43.5 feet beam, 18.67 feet mean draught, and has a displacement of 3,663 tons. At full power, under forced draft, she is expected to develop 9,000 I.H.P., and make about 20 knots speed.

Lansquenet.—This torpedo boat, which was briefly described on page 206 of the current volume, has again resumed her trials, after making numerous alterations to her machinery, such as abandoning aluminum for the pistons, etc., and it is now stated that she will not make more than 24 knots, the contract being for 26.

GERMANY.

"*F.*"—Third-class sheathed cruiser, was recently launched at Wilhelmshaven. She is 246 feet long, 33.5 beam, 15 feet draught and 1,640 tons displacement, and has twin-screw engines of 2,800 horse power, with which the speed is expected to be 16 knots. Her armament consists of eight 4-inch and four machine guns, and two torpedo tubes.

Wörth.—This first-class battleship has had satisfactory trials, maintaining 17.2 knots for six hours, with 10,087 I.H.P. and 111 revolutions of her engines. The trial was run in 33 fathoms of water.

She is 354.33 feet long on the water line, 363.25 over all, 64 feet beam, and on a mean draught of 24.37 feet has a displacement of 9,878 tons. She has a belt of nickel steel along the water line varying in thickness from 11¾ to 15¾ inches, and a protective deck of the same metal 2½ inches thick; on her barbettes the armor is 11¾ inches. Her armament consists of four 28-cm., 40-caliber rifles, and two 28-cm., 30-caliber, in barbettes; six 10.5-cm., eight 8.7-cm., two 6.3-cm., eight 8-mm., and six torpedo tubes.

Her machinery consists of twin-screw, triple-expansion engines, to which steam is supplied by twelve cylindrical boilers working at a pressure of 170 pounds per square inch.

She was built entire by the Germania Works, Kiel. Her keel was laid on the 3d of March, 1890, and she was launched on the 6th of August, 1892.

The keel of a sister ship to the *Wörth* has been laid at Wilhelmshaven.

HOLLAND.

Piet Hein.—A coast defence vessel launched recently is 283 feet long, 47 feet beam, 26.9 feet deep, 16.75 feet mean draught, and of 3,346 tons displacement. The speed expected is 16 knots.

Her engines are of the twin screw triple-expansion type, of 4,800 I.H.P., and have cylinders 27, 40 and 63 inches diameter by 27 inches stroke. There are two surface condensers with a combined cooling surface of 6,000 square feet. The main boilers are of the cylindrical type, four in number, with three

furnaces each, and contain 9,150 square feet of heating surface. There is also a smaller auxiliary boiler. The screws are four bladed, 11 feet in diameter.

She carries three 8.2-inch guns, two forward in a turret, and one aft in barbette, two 6-inch guns in broadside, ten machine guns and two torpedo tubes. Her armor is 9.4 inches thick on the turret and 6 inches on the belt.

ITALY.

Umbria.—The following additional particulars of this vessel, a mention of whose trial was made on page 620 of this volume of the JOURNAL, are at hand.

She was built by Orlando Brothers, Leghorn, and has twin-screw horizontal triple-expansion engines, with cylinders 32, 48 and 73 inches diameter, by 33 inches stroke, and surface condensers containing 10,673 square feet of cooling surface. The screws are three-bladed, 12.6 feet diameter and 15.75 feet pitch. Steam is furnished by four double-ended boilers 12.3 diameter and 19 feet long, designed for a working pressure of 150 pounds per square inch. Each boiler contains six corrugated furnaces 36.86 inches mean diameter, with a grate 6.04 feet long. The total grate surface is 445, and the heating surface 13,627 square feet.

Her official trials consisted of a run of six hours under natural draft, and one of three hours under forced draft. The results were:

	Natural draft.	*Forced draft.*
Steam pressure	125.	...
Revolutions	123.	140
I.H.P.	4,425.	7,008
Speed	17.5	19

The *Umbria's* battery consists of four 15-cm. and six 12-cm. rapid-fire guns and four torpedo tubes.

SAN DOMINGO.

Independencia.—There was launched from the shipyard of Napier, Shanks & Bell, Glasgow, on the 3d of September, a steel

screw gunboat for the Government of San Domingo. She is intended for a government yacht, and is provided with a battery of seven Hotchkiss guns. She is 170 feet long, 25 feet beam, and 12 feet 6 inches deep, and is provided with electric lights and a small search light.

SPAIN.

Viscaya.—A sister ship to the belted cruiser *Infanta Maria Teresa*, described on page 621, and built also at Bilbao, has completed her natural and forced draft trials. On the former she made 18 knots on 9,500 I.H.P., and on the latter 20.3 knots on 13,000 I.H.P. The displacement on trial was about 7,000 tons.

TURKEY.

The Turkish Government recently launched six vessels simultaneously in the Golden Horn, viz: two corvettes, two gun vessels and two gunboats. The corvettes, named respectively *Sed-ul-Bahr* and *Zuhaf*, are to take the places of obsolete vessels of the same names, and are each of 800 tons displacement and 12 knots speed. Each will carry four 4.7-inch rapid fire and six Hotchkiss revolving cannon, with two torpedo ejectors. Their engines are to be those of the ships whose names they will take. They date from 1885 only. The two gun vessels are the *Seyd-i-Deriah* and the *Shefket Numa*. Each is of 200 tons displacement, and will be armed with four small guns. The gunboats are named *Rehber* and *Ahter*. A torpedo-boat destroyer was also launched a few days ago for the Turkish Government at Kiel. She is 213 feet long, 21 feet beam, 12 feet deep, and has a displacement of 266 tons.

MERCHANT STEAMERS.

St. Louis.—The first of the two steamers building by the William Cramp & Sons' Ship and Engine Building Company for the International Navigation Company, the largest vessel ever built in this country, was launched on Monday, November 12, 1894, the ceremony having been performed by Mrs. Cleveland.

The principal data of the vessel are:

Length over all, feet and inches	554-2
between perpendiculars, feet and inches	535-8
Breadth extreme, feet	63
Depth, molded, feet	42
Depth of double-bottom, feet	4-5
Number of water-tight compartments	17
Tonnage	11,000
Displacement at 26 feet draught, tons	16,000
Indicated horse power	20,000
Speed in knots, not less than	20

The engines, each in a separate water-tight compartment, are of the quadruple-expansion type with six cylinders, on four cranks for each engine, but the diameter of the cylinders and the stroke have not been published. Steam, at a pressure of 200 pounds per square inch, will be furnished by six double and four single-ended boilers, the former 15 feet 7½ inches diameter and 20 feet long, and the latter the same diameter and about 11 feet long. The double-ended boilers contain eight furnaces each, and the single-ended ones four, making a total of sixty-four furnaces. They will be worked under forced draft on Howden's system. There are two smoke pipes of elliptical section, 11.5 by 14 feet, and 100 feet high.

In addition to the main engines, there is a large number of auxiliary engines in the ship, many of them being of the same type as those used on naval vessels built by the Messrs. Cramp. The heating and ventilating of the living apartments have been

carried out on the Sturtevant system. The Hyde capstan and windlass will be fitted, Williamson steering and ash-hoisting engines, Sturtevant blowers for forced draft, Armington & Sims electric-light engines, and Worthington feed and auxiliary pumps.

The *St. Louis* will have accommodation for the following number of passengers: first cabin, 320; second cabin, 200; steerage, 850; crew, stewards, etc., 400—total, 1,770.

The following description of the internal arrangement of the ship and of her sister, the *St. Paul*, is from "Seaboard":

In interior fittings the two vessels will conform more nearly to American ideas of comfort than most of the foreign liners. Instead of being aft, the first-class staterooms will be midships, where the ship's motion in a storm is least severely felt. The first-class saloon will be on the upper deck forward, with a domed roof, providing the utmost light and ventilation. All of the 320 first-class passengers whom the ship will carry can dine in this great apartment at one sitting. The staterooms and saloon of the 200 second-cabin passengers are abaft the first cabin, and the quarters of the 850 steerage people are in the bow and stern. In cargo capacity the *St. Louis* and *St. Paul* are limited, as all the famous greyhounds are, as compared with the distinctively freighting steamers, but they will have room for at least 125 tons more than the *New York* and *Paris*.

Although the *St. Louis* is not yet in a sufficiently forward condition to enable the visitor on board to get much of an idea of the internal arrangements, the plans are completed, and the comforts and conveniences provided for the passengers are known. Thus the quarters assigned to the different classes of ocean travelers are clearly defined. There are four decks available for living freight, and on a fifth deck are quarters for a part of the crew.

Beginning at the top, the first deck is called the shade deck. It extends from the bridge back to a point half way between the mainmast and the stern, and covers all the intervening space out to the rail on each side. It is intended, as its name implies, to give shade and shelter to the promenade deck, and is not to be used by the passengers or crew except when the latter have to

enter the boats, which are swung inboard on this deck from the davits. At the forward part of this deck, however, are the chart house, pilot house and the quarters for the captain and deck officers.

Beneath the shade deck is the promenade deck. This is a flush deck extending the whole length of the ship. At the forward end of this deck are staterooms so arranged that they can be used singly or as suites consisting of parlor, bed room and bath room.

Next to these staterooms is the ladies' deck room or drawing room, as it is called, and then comes the main companionway leading below. Other fine staterooms are located on this deck abaft the dome of the main saloon, which rises through this and the shade deck. Astern of these staterooms is another companionway leading to the saloon.

Between the two engine room skylights, which rise from the engine room through all the upper decks, is a deck pantry, which is just over the saloon pantry on the main deck. The barber shop is abaft the pantry, as are also a number of water closets and lavatories.

Still further astern, on the promenade deck, is the first-class smoking room, having a seating capacity for about one hundred persons. The second cabin ladies' room, a companionway and the second cabin smoking room comprise the remaining features of this deck.

At the forward end of this deck is a double breakwater, intended to keep the waves from washing aft in heavy weather.

The first-class smoking room, which is 32 feet long by 38 feet wide, has a large dome in the center, and it will be fitted up with every luxury and convenience. The second cabin smoking room is 32 feet long by 24 feet wide. The first-class drawing room is 30 feet long by 34 feet wide, and it will be decorated and upholstered without regard to expense.

Part of the crew have their quarters at the forward end of the saloon deck. In the forward end of the part allotted to passengers is the first-class library, which is separated from the first-class saloon or dining room by the main companionway.

Next to this comes the first-class saloon, a splendidly decorated and fitted room, 110 feet long by 50 feet wide. Over the center of this saloon rises a dome 32 feet long by 16 feet wide, having a height of 25 feet amidships above the dining-room deck. The dining-room tables are set fore and aft. There will be an organ in the saloon, with an electrical attachment which will enable the performer to play upon the instrument from the ladies' deck room.

On this deck, adjoining the engine-room skylight, are the engineers' staterooms and messroom.

Further aft is the second-cabin saloon, which is 56 feet long by 41 feet wide, and which has a seating capacity for 228 persons. Next abaft the saloon is the second-cabin companionway, forward of the doctor's room and dispensary.

Far aft on this deck is the mail clerk's room, connecting with the mail sorting room, which communicates with the main mail room below. These will all be fitted up to suit the convenience and taste of the United States Post Office officials.

The forward and after ends of the deck next below the saloon deck will be occupied by steerage passengers. Amidship are staterooms for first-class passengers, and astern of these are second cabin staterooms. Beneath the after end of the first-class saloon is the galley for the first-class passengers, and the second cabin galley is beneath the forward end of the second cabin saloon. On this deck there are twenty water closets and eight bathrooms for first-class passengers, and ten water closets and four bathrooms for second cabin passengers.

On the next lower deck the firemen, seamen and steerage passengers are quartered forward, and then come, in succession, toward the stern, staterooms for first-class and second cabin passengers, and more quarters for immigrants. There are four powerful dynamos for the electric lighting of the ship located on this deck, just below the galleys.

On the lowest habited deck are many store-rooms, the refrigerating plant, and quarters for the crew, stewards and cooks. The total number of persons in each class has been limited to such figures as will leave their respective quarters free from

crowding. The steerage accommodations are equal to those aboard any other ships afloat and superior to most. In all the steerage quarters except one the space is divided into staterooms, insuring greater privacy and comfort to the steerage passengers.

The ship is lighted throughout by incandescent electric lights, and especial pains have been taken with the ventilation. Powerful fans force the foul air out of the vessel, every compartment and every stateroom being connected with this exhaust. Pure air is drawn down from funnels above the shade deck, and is forced into every part of the ship. In cool weather the pure air is heated en route, so that the comfort of every person is provided for. The occupant of a stateroom may control the ventilation of his own apartment by turning on or off the foul air exhaust and the pure air supply. The staterooms have ventilating side lights, with automatic valves to exclude water.

In appearance they will look American in every curve and line. There is a distinctive style, a peculiar aspect of mingled solidity and symmetry, about the modern American sea-going steamer which cannot escape the eye of the veriest landsmen, and the *St. Louis* and *St. Paul* will proclaim their nationality for miles before the glass can catch the flutter of their bunting. They have the graceful, sweeping sheer and lively rise of bows which characterize American ships everywhere; the straight stem which American steamer builders were the first to adopt, and the enclosed wheel house well forward and well up above the sea, though these two latter ideas the whole world is now following. The two smokestacks are set well apart, and instead of the old-fashioned maze of yards and rigging, two steel pole masts, bearing light gaffs for signaling, comprise the whole top hamper. Twin screw steamships bowling through the brine at 20 knots from sun to sun have small need of canvas.

As to model, if the very full midship sections promise unusual stability and even suggest heaviness, the extremely fine and easy lines of the bow and stern are assurance that the expectation of high speed is not going to be disappointed. For some distance from either end of the vessel the steel outer skin is brought away

up to the highest deck, so that no unlucky sea tumbling aboard could pour its green flood into the cabins; but amidships along the sides a space is left for a fore-and-aft passageway open to air and sunlight outside saloons and staterooms. This is an American practice which has now come into vogue in nearly all of the latest ocean liners.

It is not expected that these vessels will have the speed of the *Lucania* and *Campania*, the contract with the Messrs. Cramp being that they shall make 20 knots under ordinary conditions at sea, such being the stipulation of the act of Congress granting a subsidy to these steamers.

Harvey H. Brown.—This is a steel freight steamer built for service on the Lakes. The hull was designed and built by the Detroit Dry Dock Company, and the engines by the Dry Dock Engine Works, both of Detroit, Michigan. She is engaged in the iron ore trade between Lake Superior and Lake Erie ports, returning in water ballast, making the round trip of about 1,800 miles in seven to eight days. During one of these trips, a test of her performance was made by Geo. C. Shepard, Esq., of Cleveland, which forms the subject of an interesting little book issued by the Detroit Dry Dock Company, from which the following information has been taken:

Length, over all, feet and inches	359-2
Length, between perpendiculars, feet	342-0
Beam, molded, feet and inches	42-1
Depth, feet	25-0
Draught, light, feet, forward	2.
aft	13.
Displacement, net tons	2,485.
Area immersed midship section, square feet	300.5
Area of wetted skin, square feet	17,335.
Block coefficient of fineness	.828
Angle of entrance, degrees and minutes	49-44
Draught, loaded, feet and inches, forward	14-10
aft	14-11
Displacement, net, tons	5,365.
Area immersed midship section, square feet	608.2
Area wetted skin, square feet	23,332.
Block coefficient of fineness	.94
Angle of entrance, degrees and minutes	63-44

The main deck beams are not decked over except by a strip of steel 3 feet wide around the sides. The spar deck is of steel. Accommodations for officers, crew, mess rooms, galley, etc., are provided in a topgallant forecastle and other deck houses. The engine is in the after end of the vessel with working floor on the main deck, and the boilers are immediately forward, also on the main deck. The coal bunkers are on this deck forward of the boilers and extend the whole width of the ship. A ballast bottom 42 inches deep extends from frame No. 12 to frame No. 133, the entire width of the ship, and is divided into ten compartments, five on each side of the keel, and each having an independent connection to the ballast pump and to the sea cock. The aggregate capacity of the ten compartments is 1,000 tons, and they are numbered 1 to 5 beginning at forward tank. The bottom of the ship is sheathed with oak plank 5 inches thick, from a point 20 feet aft of the stem, to within 40 feet of the stern post, and coming up on the bilge 30 inches above the keel. The ends are faired off with a plate 8 feet long, the space between plate and skin being filled with cement.

The main engines are of the triple, inverted vertical type with the H.P. cylinder between the I.P. aft and L.P. forward; air pump, bilge and cooler pumps driven by a beam attached to the L.P. cross-head; crank shaft 12 inches diameter, continuous, on four journals with H.P. crank leading, I.P. next and L.P. last in the sequence. The H.P. valve is of piston type operated by Joy valve gear, while the I.P. and L.P. valves are double-ported slide valves worked by two eccentrics through Stephenson links.

The cylinders are 22, 35 and 56 inches diameter and 44 inches stroke, and the connecting rod 11 feet between centers.

A jet condenser condenses exhaust from the L.P. cylinder.

The air pump is 28 inches in diameter by 18 inches stroke, and the diameter of the trunk 14 inches. The circulating pump is of the duplex type, with steam cylinders 6 inches in diameter, water cylinders $7\frac{1}{2}$, and the common stroke 8 inches.

The propeller shaft is 12 inches diameter and 30 feet $1\frac{1}{2}$ inches long. The propeller is of cast-iron with adjustable blades; it is

four bladed, 13 feet 2 inches diameter and 16 feet pitch, and has a projected area of 49 48 square feet.

There are two cylindrical main boilers worked under forced draft on Howden's system.

The following are their particulars:

Steam pressure, pounds	160.
Diameter, feet	13 5
Length, feet	12 2
Furnaces (two in each boiler), inside diameter, inches	48.
Length of grate, feet	5.5
Tubes, number each boiler	328.
diameter, inches	2 5
length between tube sheets, feet	8.25
Grate surface, both boilers, square feet	88.
Heating surface, both boilers, square feet	4,130.

Each boiler is fitted with a Craig circulating apparatus.

There is also a donkey boiler of the vertical type, 4 feet diameter and 8.67 feet high, containing 8.7 square feet of grate and 243 of heating surface.

The air supply to the furnaces of the main boilers is furnished through the Howden system of hot draft, which consists of a fan 54 inches diameter driven directly by a pair of horizontal engines 5 inches diameter and 5 inches stroke. From the fan, which is located in the engine room, a trunk leads through to the front of the boilers, where it enlarges into a large box in the boiler breechings, the lower side of the box being immediately above the upper row of boiler tubes. Passing vertically through this box are 412 3-inch tubes, 4 feet 6 inches long, and through which the gases must pass on their way to the uptake. The air is led down to the valves and admitted above and below the grates. The fire doors and ash pit doors are air tight, and before opening the fire door for any purpose, the valves admitting air below the grates are closed.

There is one smoke pipe 5.5 feet diameter and 40 feet high above the grates.

A feed water heater is fitted consisting of a piece of 6-inch pipe, 4 feet long; the cold water from the circulating pump and

the exhaust from the auxiliaries enter at the top, and the heated water is drawn from the bottom.

The following is an abstract of the results reported for some of the tests:

Number of Test.	1	2	3	4	5	6
Date, July	2	6–7	7–8	8	9	10
Duration of coal test	8^{18}	8^{18}	5^{40}	1^{40}	8^{00}	4^{45}
Tons displacement	2,485.	2,485.	5,390.	5,365.	5,365.	5,335.
Mean steam pressure	154.25	152.45	156.2	170.	156.25	151.6
I.P. receiver pressure	54.75	64.5	56.5	50.	51.3	58.5
L.P. receiver pressure	11.75	13.5	12.85	12.	12.5	15.
vacuum	21.5	21.3	21.36	22.05	21.48	21.01
revolutions fan, per min.	4.31	4.20	4.18	4.60	4.31	4.15
temperature air outside	67.	49.	50.	51.50	69.	72.
at fan	.....	.....	78.	80.	85.3	89.
at furnace	273.	223.	182.5	189.	187.	186.
in uptakes	597.	622.	470.	520.	487.	471.
feed water	147.57	149.25	148.9	146.5	148.3	152.7
Pressure air at fan, inches	2.9	2.77	2.75	3.2	2.88	2.7
furnace, inches	.4	.41	.52	.7	.55	.52
uptakes, inches	.....	.2175	.188	.188	.125	.156
Mean revs. main engine, per min.	84.54	81.22	82.22	86.26	81.37	77.56
Speed in miles per hour	14.51	13.94	13.46	14.06	13.2	12 63
Slip, per centum	5.8	5.5	9.9	10.4	10.6	10.7
I.H.P., total	1,287.	1,186.6	1,293.	1,428.2	1,266.5	1,121.1
air pump	13.	12.7	13.25	23.	18.4	11.7
Ind. water consumption in L.P.	12.7	12.06	11.68	12.	11.57	10.62
Water by meter per I.H.P. per hour	16.4	16.5	16.5	18.2	16.6	16.3
Coal per hour	2,397.	2,496.9	2.647.	2,634.	2,375.	2,105.
Combustible per hour	2,132.	2,223.	2,342.	2,345.	2,113.7	1,873.
Coal per sq. ft. grate per hour	27.2	28.3	30.	29.3	27.	23.9
sq ft. heating surface per hour	.58	.6	.64	.63	.57	.51
I.H.P. per hour	1.86	2.10	2.04	1.84	1.87	1.88
Com. per I.H.P. per hour	1.65	1.87	1.84	1.64	1.66	1.65
Apparent evap. per lb. coal	8.79	7.87	8.09	9.87	8.87	9.11
per lb. comb.	9.89	8.84	9.14	11.09	9.96	10.23
Water from and at 212°, per lb. coal	9.81	8.77	9.02	10.68	9.88	10.17
Water from and at 212°, per lb. combustible	11.03	9.86	10.2	12.	11.11	11.42
I.H.P. per sq. ft. grate per hour	14.6	13.5	14.7	16.2	14.4	12.7
Indicated thrust, net tons	15.69	15.06	16.21	17.67	16.04	14.9

Retarders made of strips of iron $\frac{3}{32}$ inch thick and 2¼ inches wide, twisted into a screw of four turns in the length, were put into all the boiler tubes before test No. 3.

Besides the engines already mentioned, there are the following:

One duplex feed pump $7\frac{1}{2} \times 4\frac{1}{2} \times 10$ inches, taking water from hot well of air pump, or from feed water heater.

One duplex service pump $7\frac{1}{2} \times 4\frac{1}{2} \times 6$ inches.

One duplex ballast pump $10 \times 14 \times 10$ inches.

One dynamo engine, double, single acting, 8×7 inches.

One steam steering engine.

One windlass engine, capstan engines and cargo hoists.

The total weight of the machinery and water, with 12 inches of coal on the grates, is 291.6 net tons.

The method of making the coal tests was to start on weighed coal after the fires had been cleaned, noting the time of putting the first shovelful of the weighed coal on the fires, for the beginning of the test, continuing the firing of weighed coal as long as desirable, and then noting the time of putting on the first shovelful of the unweighed coal, for the end of the test. Fires were cleaned every six hours, and the tests generally ran through one cleaning.

The water supply of the feed-water heater was taken from the sea cock, and its temperature raised about 100 degrees; but had the piping been so arranged that the supply could have been taken from the the hot well, the temperature of which was only 6 or 7 degrees below that of the feed-water, the temperature of the feed-water could have been made 30 degrees higher than it was.

Louisiana.—This well known steamer of the Cromwell Line, running between New York and New Orleans, has recently been fitted with new machinery by the Newport News Shipbuilding and Dry Dock Co., under the direction of Mr. Horace See. She was built in 1879 by John Roach & Son, at Chester, Pa., and is of the following dimensions:

Length over all, feet	349.
Length between perpendiculars, feet	324.
Breadth, molded, feet	39.
Depth, molded, feet	27.6
Draught of water, maximum, feet	22.
Displacement at above draught, tons	5,200.
Gross tonnage with old machinery	2,840.

She is a two-deck vessel, with wide deck houses and forecastle. All her passenger accommodation is above the main deck. A feature of her original construction was the absence of a shoe connecting the rudder-post and keel, the lateral stiffness of the former being maintained by the end of the propeller shaft, which extended into a bearing in it.

Her machinery was built by the Delamater Iron Works, and consisted of a twin vertical compound beam engine, with high pressure cylinders 30 inches diameter and 72 inches stroke, and low pressure cylinders 56 inches diameter and 86 inches stroke, with valves of the poppet type ; and eight externally fired, return tubular boilers 8.5 feet diameter and 12.17 feet long.

The new machinery of the *Louisiana*, just completed, consists of a vertical three-cylinder, triple-expansion engine constructed and fitted on board by the Newport News Shipbuilding and Dry Dock Co., of Newport News, Va. By introducing a lighter and more economical type of machinery, the coal consumption of this ship will be considerably reduced, consequently part of the old coal bunker will be available for freight space, the dead weight capacity of the vessel considerably increased, while the speed of the vessel will be somewhat higher than with the old machinery.

The old boilers have been replaced by two double-ended Scotch boilers, made of open hearth steel, 12 feet 9 inches mean diameter of shell and 20 feet in length. The working steam pressure is 170 pounds per square inch. The smokestack is smaller in diameter and higher than the old one. The donkey boiler, of the same type as the main boilers, is 8 feet diameter and 8 feet 6 inches long. Inspirators and hydrokineters are used as circulating apparatus for the main boilers. The fresh water supply is from tanks and also from an evaporator of 10 tons capacity.

The main engine is a vertical, triple-expansion, surface condensing, direct-acting one, with cranks at 120 degrees. The cylinders are of the following dimensions: High pressure cylinder, 24 inches ; intermediate cylinder, 39 inches, and low pressure cylinder, 64 inches in diameter by 45 inches stroke of piston. All

cylinders have valves of the piston slide variety, placed in front of engine and operated by the See-Marshall valve gear. The condenser forms part of the engine framing.

Air and bilge pumps are worked by levers from the low pressure cylinder crosshead. The circulating pump is centrifugal, and driven by an independent engine. An independent Blake duplex feed pump, connected to the forward and after ballast tanks, and to condenser, is used for feeding the boilers. Besides this, there are two Blake duplex donkey pumps, one of which is used as an auxiliary feed pump, as well as for general donkey purposes.

The main journals are lined with white metal; the thrust bearing is of the Smith pattern, and also lined with white metal. The main pistons are made of cast-iron, and fitted with adjustable followers, thus dispensing with the extended piston rods for guiding them. The crank shaft is built up, pins and shafts of steel, slabs of iron. The old line shaft has been retained, except the thrust piece. The end of the tail shaft has been cut off where it extended into rudder post, and a shoe has been added connecting rudder post and keel.

The See patent hydro-pneumatic ash ejector is fitted in the after fireroom; the hopper into which the ashes are shoveled is placed in a recess built in the coal bunker in the after fireroom. The ashes are carried on a railway from the forward fireroom to the after one. From the lower part of the hopper a discharge pipe, 6 inches internal diameter, extends upward at an angle of about 60 degrees to the horizontal, leading overboard under the main deck, the discharge opening through the side being located about 4 feet above the water line at load displacement. To the bottom of the hopper is also attached the ejector and jet cock, connecting with a special independent Blake duplex pump 10 inches × 6 inches × 12 inches.

The advantages expected from the new machinery are 25 per cent. less fuel, space for 500 more bales of cotton, and an engine room force of five men less than with the old.—[From the "Marine Journal."]

Kensington.—A short description of this vessel, one of the

two new twin-screw freight steamers belonging to the International Navigation Company, was given on page 217, since which time complete description of the ship and machinery have appeared in "Engineering," from which this is taken.

The *Kensington* was built by Messrs. J. & G. Thomson, Clydebank, and may be taken as a representative of a type which is increasing in favor with the large passenger lines. It is being more and more recognized that high speed is almost incompatible with cargo carrying to any great extent, and the leading Atlantic lines are now adding to their fleets what may be termed intermediate steamers, where cargo is to form an important item in the revenue, while at the same time the comfort of the passenger accommodation is equal to that in the high speed vessels, although the duration of the ocean voyage is 30 per cent. longer. This latter fact greatly affects the expenditure, so that it is not difficult to arrive at the conclusion that under ordinary conditions the type of which the *Kensington* is a good representative, may be a better dividend earner than even the modern "greyhound." The *Kensington*, for instance, carries 10,600 tons of cargo and at the same time 120 cabin passengers; the modern fliers seldom carry more than 2,000 tons of cargo and perhaps 600 cabin passengers. The point to be determined is as to whether the capacity of the former will be more largely and more constantly utilized than the latter.

Her dimensions are:

Length between perpendiculars, feet	480
Breadth, molded, feet	57
Depth, feet	40
Gross tonnage, tons	8,670

In a vessel such as this, which is intended to cross the North Atlantic at all seasons of the year, and with very large cargoes of varying density, the question of structural strength is of the first importance. The vessel is framed on the cellular double-bottom principle, the distance between the outer and inner skins being generally about 4 feet. The vertical keel plate is 48 inches in depth, with double angles on top and bottom edges. It ex-

tends continuously for the whole length of the ship, and is made water-tight for the midship portion of the ship, so that the midship compartments of the ballast tank can be used for correcting any heel which the ship may get. The edge plates of the tank are, of course, continuous, and three intermediate intercostal girders are fitted between the center keel plate and the edge plate on either side. The floor plates, which are spaced 30 inches apart, and are ½-inch in thickness, extend in one plate from the vertical keel to the edge plate, and are lightened by oval manholes 30 inches by 20 inches between the intercostal girders. These manholes were punched out in one operation by a hydraulic machine. The inner bottom plating is 1 inch in thickness under the engines, ¾ inch under the boilers, and less than ½ inch at the ends of the ship. The butts and edges are overlapped, except under the engines, the butts being treble, and the landings double riveted.

Under the engines the double bottom is somewhat increased in depth, additional longitudinal girders are fitted, and the thickness of the floor plates is increased to nearly ¾ inch. The bed plates of the engines are bolted directly to the inner bottom, thus giving a thoroughly rigid foundation for the machinery. Outside the limits of the inner bottom the framing is almost entirely of channel bars, which have to a very great extent superseded the old system of frame and reverse bar in vessels of this size and class. The channal bar also has advantages over the Z-bar section, which is almost exclusively employed for vessels of the British Navy, as, owing to the form of the channel section, the bars lie flat on the slabs when in process of bending or beveling, which is not the case with the Z-bar section. The frames of the *Kensington* are 7 inches deep, spaced 30 inches apart. Webb frames formed of plates 36 inches deep, with double angles on their inside edges, are fitted at close intervals both in the machinery compartments and in the cargo holds.

The beams of the upper, main and lower decks are also of channel steel, 8 inches deep and spaced 30 inches apart. They are supported by three rows of pillars, and at the head of each row of pillars a longitudinal girder is fitted. The upper, main

and lower decks are each plated with steel from end to end of the ship. The shell of the ship varies in thickness from nearly 1 inch to little over $\frac{1}{2}$ inch at the ends, the average thickness amidships being about $\frac{3}{4}$ inch. The plates are generally about 26 feet long and 62 inches wide, and the butts of all, except the sheerstrake, are overlapped and quadruple-riveted amidships and treble-riveted at ends. The sheerstrake butts have double straps treble-riveted, and the sheerstrake is doubled for three-quarter length amidships.

The water-tight bulkheads, which are nine in number, extending from the keel to the upper deck, have been spaced so that even in the event of two adjacent compartments being flooded the ship would not only float, but would still have considerable freeboard and be capable of steaming. The bulkheads have been constructed in accordance with the recommendations of the Bulkhead Committee. The part of the bulkheads below the lower deck is stiffened by 10-inch vertical Z-bars spaced 30 inches apart, connected by knee plates to the tank top, and having their upper ends connected to the lower deck plating. On the opposite side of the bulkhead, at the height of the orlop stringer, a horizontal girder 30 inches deep is fitted. The upper part of the bulkheads, where the water pressures would not be so great, is suitably stiffened by lighter channel or angle bars.

The pumping arrangements are carried out in the most modern and complete manner, and by a special arrangement the water can be pumped from one tank to any other for the purpose of trimming the ship. The pumping arrangements for freeing the bilges of water are also of a very powerful and complete character, and in addition to these, large ejectors are fitted in the engine space, which, being controlled from the upper deck, can be set to work even in the event of the pumps being disabled or submerged.

The *Kensington* is the largest cargo carrier in the world, as when loaded to her Plimsoll mark she will carry 10,600 tons all told. The vessel is fitted with very complete arrangements for handling the cargo expeditiously, there being 10 powerful steam winches of Messrs. Clarke, Chapman and Co.'s most im-

proved make, fitted near the hatches on the upper deck, and worked in conjunction with strong derricks, of which there are no less than 16, of lengths varying from 40 to 60 feet.

The winches are of the makers' ordinary horizontal type, having cylinders 7 inches in diameter by 12 inches stroke. There are 10 on board, constructed to work at 200 pounds pressure, each fitted with extra large warp ends and whipping drums. Crinoline drums are fitted over the barrels; thus very quick lifts can be obtained.

There are large state rooms amidships on the upper deck, while the accommodation for the officers of the ship is near their work on the lower bridge or adjoining the engine room. On the bridge deck is situated the dining saloon, a well-lighted commodious apartment, panelled and finished in polished oak, capable of dining 126 persons. This saloon is entered from either the bridge deck through a large vestibule, or from the upper deck, where the state cabins are situated, by a wide staircase. The ladies' room, which is also on the bridge deck on the port side of the funnel casing, is also entered from the saloon vestibule. A large pantry is fitted up on the starboard side of the funnel casing. At the after end of the bridge deck a comfortable and well-appointed smoking room is situated. Above the dining saloon a strong steel house is built, containing a sitting room and bed room for the captain, and rooms for the principal officers, as well as chart and wheel houses; and surmounting the whole structure is the navigating bridge, at a height of 44 feet above the water when the ship is loaded. From this an exceptionally clear and unobstructed look out is had both fore and aft of the ship. Accommodation for the ship's crew is provided under the forecastle, and provision is made under the poop for a large number of cattlemen, in the event of cattle being carried, for which suitable arrangements have been made. Accommodation is also provided for carrying over 1,000 emigrants on the main deck. Great care has been bestowed on the ventilation, heating and sanitary arrangements of these spaces.

The vessel is steered by a very large single plate rudder, the weight of which is carried inboard, there being no bearing pintles

in the rudder frame. The rudder is actuated by Messrs. Brown Brothers' steam steering gear working direct onto the rudder head, and controlled from the bridge by Messrs. Browns' telemotor gear. Strong relieving tackles are also fitted to the tiller. The appliances for handling the ship are very complete, and of the most powerful and modern character. A very strong vertical windlass is mounted on the forecastle for working the anchors. This windlass is provided with large warping drums, so that a separate warping capstan is not required. The engine, which is placed aft of the windlass gear, is of the vertical type, having two cylinders, 12 inches in diameter by 12 inches stroke. The windlass is fitted with the siding spring brake and special frictional lifting purchases, the cones being fitted with hardwood blocks, which have been found most durable and efficient. The windlass side frames are built up of steel plates and angles, the bearings being steel castings. This not only makes a strong but also a light frame, which is a great advantage when so large a piece of machinery is placed on the forecastle of a ship. There are four warp ends, two on the main shaft and two on the intermediate shaft, which is extended to take them; all are fitted with whelps.

The cables are $2\frac{5}{8}$ inches in diameter, and are led in under the cable lifters, then over and down a pipe at the forward corner of the bed plate. The hawse pipes are made large enough to stow the anchor stocks in them if so desired. A powerful double-geared steam winch is mounted on the poop for warping purposes, and the leads for the steering gear relieving tackle are also taken to this winch.

The engines are of the quadruple-expansion type, each with four cylinders, and each cylinder on a separate crank. The order of the cylinders from the forward end is high pressure, second intermediate, first intermediate, low pressure. The cranks are at right angles to each other, the sequence of turning being high, low, second intermediate, first intermediate. The diameters of the cylinders are $25\frac{1}{2}$, $37\frac{1}{2}$, $52\frac{1}{2}$ and 74 inches, and the stroke 54 inches. The low pressure cylinder has a double-ported slide valve of Thom's patent and the others piston valves, and all are worked by radial gear. It is operated by a single eccentric,

through a quadrant rocking on trunnions, and the reversing is accomplished by moving a sliding block attached to the valve stem from one end of the quadrant to the other. Lap and lead are obtained from a separate lever worked from the main engine crosshead. This arrangement of the valve gear allows of the valves being placed at the back, thereby bringing the centers of the cylinders much closer together and economizing space in the engine compartment, and, of course, adding to the cargo capacity in the ship. The total length of the engines is about 25 feet, which is much less than could be attained if the ordinary link gear had been used. The reversing gear is controlled by Brown's well-known steam and hydraulic direct-acting engine. In the construction of the engines cast steel has been largely used.

The shafting is of Siemens-Martin steel. The four cranks are each built up separately, and are interchangeable. The crankshaft is 14¾ inches in diameter, the thrust shaft 14 inches, and the tunnel shaft 14 inches. The thrust blocks are of the ordinary horseshoe type, of white metal, and there are seven rings. The blades of the propeller are of manganese bronze, while the boss is of cast steel. There are three blades to each propeller, the diameter being 17 feet, and the pitch 20 feet.

The condenser is oblong, and supports the back of the cylinders. It is 19 feet long, of cast iron, and is fitted with brass tubes, the cooling surface being about 10,000 square feet. The condensing water to each condenser is circulated by a large centrifugal pump driven by an independent engine. The air pumps are driven by a lever working from the crosshead of the low pressure engine in the usual way. There is also fitted a large evaporator to produce the necessary fresh water from sea water to make up the feed, and to avoid the use of salt water in the boilers. A large feed heater and filtering arrangements are provided. An auxiliary condenser has, in addition, been fitted on board, with a separate circulating pump, so that all the auxiliary machinery in the ship is worked separately from the propelling engines. An installation of Worthington pumps has been fitted on board.

There are three boilers in the ship, constructed of steel, and

adapted for a working pressure of 200 pounds to the square inch. Two of the boilers are double-ended, and are 15 feet 9 inches in diameter by 21 feet 5 inches long, while the single-ended boiler is of the same diameter, but 11 feet 3 inches long. There are four furnaces at each end, making 20 in all, each with a Purves flue. These are 3 feet 4 inches mean diameter, the length of firebar. being 5 feet 9 inches. The total heating surface is 12,176 square feet, and the grate surface 383 square feet. The boilers are fitted with "Serve" tubes 3¼ inches in diameter, with 1⅝-inch spaces between. There is fitted a system of induced draft as elsewhere described in the JOURNAL. The boilers are in one compartment and exhaust into one chimney, which is 84 feet high from the grate level, and elliptical in plan, 14 feet by 9 feet. The fans are 7 feet 6 inches in diameter, and are driven direct by Sturtevant engines running under ordinary conditions at a speed of 370 revolutions. The fans induce a draft through the furnaces, the air having previously been heated by passing through tubes placed in the way of the waste gases from the furnaces. The inlet of air to the furnaces is through tubes placed in a casing over the boiler, thence down a passage in front of the smokebox at the end of the boilers, and into the furnaces. The gases from the furnace, after passing through the boiler, play around the tubes forming the air inlet, and subsequently pass into the funnel, at the base of which are the five fans inducing draught through the passages thus briefly indicated.

An extensive installation of refrigerating machinery is provided in separate sections, one section for perishable cargo, the other for ship's requirements. In connection with the latter there are large ice houses and storerooms fitted on the main deck, on the principle adopted by Messrs. Kilbourn & Co., of Liverpool This firm supplied all the refrigerating plant on board.

A complete installation of electric light, consisting of about 500 incandescent lamps, has been fitted up by the builders' electrical staff. The generating plant consists of three duplicate sets of direct-driven engines and dynamos, the engines being of the two-cylinder vertical type by Belliss, and the dynamos by Crompton, London.

Elaborate arrangements have been made for extinguishing fire, powerful fire engines, with connections to all compartments on main, upper and bridge decks, being provided, in addition to the steam fire extinguishers fitted to all the holds.

At the trials on the measured mile at Skelmorlie, the displacement of the vessel was 12,400 tons, the draught being—forward, 21 feet 9 inches; aft, 21 feet 7 inches; mean, 21 feet 8 inches. Six runs were made, the mean results being as follows:

	Starboard.		*Port.*
Steam pressure in boilers		199.5	
Air pressure		3.16	
Revolutions of main engines	86.9		86.4
Vacuum	27.		27.
I.H.P.	4,329.		4,074.
Total		8,313.	
Speed		15.8	

The I.H.P. per ton of engines is 12; per ton of boilers, 12, and per ton of machinery, 6.

On her first trip from Liverpool to Philadelphia, she averaged 14.1 knots per hour, and on the return 13.7 knots, the I.H.P. developed being about 7,000.

Globe.—This is a Lake freight steamer recently built by the Globe Iron Works, of Cleveland, Ohio, who claim that she is the strongest vessel on the Lakes.

Her leading particulars, according to the "Marine Review," are:

Length, keel, feet	328.5
Length over all, feet	348.5
Beam, feet	42.
Depth, molded, feet	28.
Capacity, cargo, 18 feet draught, tons net	4,218.
coal bunkers, tons net	250.
water bottom, tons net	1,400.
Engines, vertical triple-expansion.	
High pressure cylinder, diameter, inches	24.
Intermediate cylinder, diameter, inches	39.
Low pressure cylinder, diameter, inches	63.
Stroke, inches	42.

Boilers, two of Scotch type.	
Diameter, feet	16.
Length, feet	12.5
Weight of each boiler, tons	70.
Diameter of furnaces (four), inches	46.
Propeller, sectional.	
Diameter, feet	14.
Pitch, feet	17.

The material throughout this steamer is open-hearth steel made to required tests at the mill and subject to approval at the ship yard. All scantlings were increased over ordinary construction, and through the sheer strake the thickness is 2 inches. The requirements as to material exceeded the rules of the United States Standard Register of Shipping in a very large measure, and the vessel is given the highest class awarded by that association. A 54-inch water bottom runs the entire length of the vessel and it is divided into eight compartments, having an aggregate capacity of 1,400 net tons. In coarse freight her capacity is calculated as follows on the draughts noted:

Draught.	*Capacity, net tons.*
15 feet	3,000
16 "	3,390
17 "	3,785
18 "	4,218

On 18½ feet draught it is calculated that she will carry 151,000 bushels of wheat, allowing an open space of one foot below deck beams.

Steam windlass, steam capstans and steam steerer, as well as the several other late appliances suited to a ship of this kind, were made by the builders. There are two separate electric plants, each of 120 lights, installed by the Fisher Electric Manufacturing Company of Detroit. When the boat is under way it will be necessary to use only one of the plants, but when handling cargo in port the entire equipment may be utilized. Another feature peculiar in this boat is an increase in bunker capacity, which is secured by carrying the boiler house forward, and thus providing space for extra fuel that is usually carried on

deck on trips up the lakes. In the forward house there are in addition to captain's quarters of the usual kind, two spare rooms with bath rooms, closets, etc. Quarters for the crew are roomy and in every way equal to provisions made in this regard on the best of lake freight steamers.

Guelph.—A twin-screw steamer, built by Harland & Wolff for service between Southampton and South Africa. She is 400 feet long, 47 feet beam, 31 feet deep, with a gross tonnage of 4,916, and a deadweight capacity of 5,724 tons. She has nine transverse bulkheads, and a double bottom capable of holding about 1,000 tons of water ballast. She has a large forecastle and poop, with a central bridge house equal to half the length of the vessel, and over it a boat deck, where passengers are allowed to promenade. The ladies' music saloon is forward, while under it is the first-class dining saloon arranged for forty-five passengers. On the upper deck, ranged along either side of the ship, are the first-class cabins, the smoking room being aft. The second-class passengers are housed in the poop on the upper deck, with dining saloon and drawing room, while the steerage passengers are below on the main deck. There are accommodations for 300 passengers of all classes.

The engines are of the triple-expansion type of 2,350 I.H.P., giving the ship a speed of 12 knots, and work at a pressure of 180 pounds. The cylinders are 18½, 30, and 50 inches in diameter, with a stroke of 42 inches. The high pressure cylinder has a piston, and the other two, slide valves, each worked by the ordinary double eccentric link motion. The cylinders are separate castings, the usual A-columns in the front being cast with an extension at top, flanged, so that the three columns are bolted the one to the other. The result is said to be a marked decrease in vibration as compared with the more largely adopted method of connecting the cylinders rather than the columns. The condenser, as is usual, forms part of the back supports. It has a cooling surface in each engine of 1,796 square feet. The pumps are worked from the crosshead of the intermediate engine. The working parts of the engine are of forged steel, the crankshaft being 10¾ inches in diameter, the tunnel shaft 10½ inches, and

the propeller shaft 11 inches. There are four thrust rings of the horseshoe type. The propellers are three-bladed, and are 13 feet 9 inches in diameter. The framing and plating of the ship are bossed out so as to reduce the length of the shafting outside. Immediately aft the engines the shafts are in one compartment, the center of which is occupied by the electric light and refrigerating machinery, which is thus immediately under the direct care of the engineers. Weir's pumps and evaporator, centrifugal pumps, and the other etceteras are placed in the wings in the main engine-room. The electric machinery is by Messrs. W. H. Allen & Co., the dynamo running at 250 revolutions, 150 amperes and 80 volts.

Steam is supplied by two large double-ended boilers each with six furnaces; the grate surface is 238 square feet, and the heating surface 7,658 square feet. The boilers are in one compartment, a large space separating the engine and boiler compartments being given over to coal bunkers, with a passage between each. On either side of the ship, again, are coal bunkers, while in the forward end of the compartment are coal bunkers on either side, with a single-ended two-furnace boiler in the center working at 180 pounds pressure, supplying steam to all the auxiliary engines. These latter include Pirie's well-known steering gear, four heavy steam winches, &c. The bunker capacity, it may be added, is sufficient for fuel for the round voyage to the Cape, so that the vessel need only take in coal at the port where prices are lowest.

The carriage of perishable goods is an important item in these intermediate steamers, and the refrigerating installation on board the *Guelph* may be specially referred to. It consists of one of J. and E. Hall's patent carbonic anhydride refrigerating machines made on their duplex type. The machine consists of a compound steam engine with cylinders side by side working on one crankshaft, and driving by their tail-rods two carbonic anhydride compressors. In the bed of the machine are arranged two condensers for liquefying the carbonic anhydride, these condensers consisting of long lengths of solid drawn copper tube. There are also two evaporators consisting of nests of wrought-iron piping contained

in steel casings, and there are also two steam-driven brine pumps. The system is, therefore, entirely in duplicate, each compressor being connected up with its own condenser and evaporator, and, by means of a coupling, either compressor can be thrown out of gear, leaving the remaining one still at work. The brine cooled in the evaporators is circulated throughout the brine pipes in the various chambers. The insulated space is divided up into five different rooms, thus, those for fish, milk and meat being kept at the lowest temperature, that for vegetables, &c., at another temperature, and the large room for the storage of fruit cargoes being kept at another temperature. The circulation of brine in the latter is arranged in a special manner to enable the temperature to be kept with practically no variation, the air, moreover, being caused by natural means to be kept in constant circulation.

Norman.—Another steamer constructed by Harland & Wolff for the Union Line, and intended for the same trade as the *Guelph.* Unlike the latter vessel, the *Norman* has been constructed for speed, as she is to carry the mails, and is expected to make about 18 knots an hour. She is of the following dimensions:

Length over all, feet	500.
Length between perpendiculars, feet	490.
Breadth, molded, feet	53.
Depth, molded, feet	37.5
Gross tonnage	7,392.

One feature in her construction is that the shafts are carried inside the ship, the hull being built out around them, and that the keel is cut away aft so as to form an aperture in which the screws revolve. The screws overlap, and one is placed forward of the other, as in the *Teutonic* and *Majestic.* She has accommodations for 250 first and 100 second-class, and 160 steerage passengers.

Vienna.—A twin screw steamer, built by Earle's Shipbuilding and Engineering Company, of Hull, England, for the Great Eastern Railway of England.

She is 302 feet long between perpendiculars, 36 feet beam, 16

feet 3 inches deep, is divided into eight water-tight compartments, and was built under a guarantee to make 17.5 knots.

Her engines, which were designed by Mr. E. A. Seaton, are of the usual triple-expansion type, with cylinders 26, 39½ and 61 inches diameter by 36 inches stroke. The piston rods are 6¾ inches diameter, the connecting rods 8 feet from center to center, and the crank shaft 11¾ inches in diameter. The engines are placed abreast of one another in the engine room, with the cylinders inclined towards the center line of the ship. They are placed on extra strong seatings, and are well tied together to prevent the vibration which is often noticeable in ships of this class with fast-running machinery. The cylinders are supported at the back by cast-iron columns which carry the guides, and on the front side by round wrought-iron columns turned bright. The surface condensers, which have a total cooling surface of 6,200 square feet, are cylindrical, and have wrought-iron bodies fitted with cast-iron waterways. They are placed in the wings of the engine room, and connected to the low pressure cylinders by copper pipes.

The air pumps, which are of gun-metal, 27 inches in diameter with a stroke of 13 inches, are worked from the low-pressure piston-rod crossheads, and discharge into feed tanks placed under the condensers on each side of the engine room. There are no feed or bilge pumps worked direct from the main engines; the boilers being supplied by two powerful vertical duplex pumping engines of the Worthington type. These pumps draw from the feed tanks in the engine room, and are controlled by automatic float gear. A vertical duplex pumping engine is also fitted in the engine room as an auxiliary feed pump. Two large vertical duplex pumps, also of the Worthington type, are fitted for pumping out the bilges, ballast tanks, sanitary tanks, etc., and for use as fire pumps, washing decks, etc., through the fire-service pipes fitted along the upper deck. Water is circulated through the surface condensers by two 12-inch centrifugal pumps, which are connected across the ship, so that in the event of one breaking down, the other could be worked on both condensers at the same time. These pumps are also ar-

ranged to draw from the bilges and discharge overboard. The remaining auxiliary machinery consists of an evaporator, a feed-water heater, two fans, driven by independent engines, for ventilating the cabins; a pulsometer for supplying water to the sanitary tanks; a steam ejector for drawing from the bilges and discharging overboard; a direct-coupled engine and dynamo, steam steering engine, and two forced draft fans. The electric light machinery is placed in the space abaft the engine room bulkhead. Three steam winches of improved design, with helical gearing, are fitted on the upper deck, together with a steam capstan.

Steam is supplied to the main engines by five single-ended return-tube boilers, with three furnaces in each. These boilers are placed in groups of two and three, in two boiler rooms, separated by a water-tight bulkhead. The boiler rooms can be closed, and the boilers worked under moderate forced draft when desired; but the ventilation is so efficient that forced draft is not considered necessary, save under very exceptional circumstances. The boilers are made entirely of steel, and work at a pressure of 160 pounds per square inch. They are 14 feet 3 inches diameter and 11 feet 6 inches long, and contain 357.5 square feet of grate, and 11,450 of heating surface. In addition to the main boilers, a donkey boiler, working at 90 pounds per square inch, is fitted, from which the winches and auxiliary machinery may be driven. The steam and feed pipes are of wrought iron, and are so arranged that the boilers may be worked in groups, and each group with its pipes and connections shut off entirely from the others, in the event of any mishap to either of them.

Her official trial consisted of six runs over the measured mile, and a continuous run of 85 miles. During the former, the engines made 134 revolutions per minute, and during the latter 132.4, the mean speed being 18.3 knots and the I.H.P. 5,230.

The same company has also built three similar vessels for the same line.

Duke of York.—A short description of this fast steamer was given on page 636 of the last number of the JOURNAL, but the

following more complete description is added from "The Engineer":

Length between perpendiculars, feet	310
Breadth of beam, molded, feet	37
Depth, molded, feet	17
Height between main and lower decks, feet	8
Height between upper deck and poop bridge and forecastle decks, feet	8
Indicated horse power	4,000
Speed, knots	19

Stateroom accommodation is provided for 230 first-class passengers, and steerage apartments for a proportionate number of third-class passengers, together with drovers' room, and complete equipment for officers, firemen and seamen. The staterooms are of a very superior type; there is plenty of space in them, spring mattresses, and excellent ventilation. The principal saloon is a very handsome apartment, fitted with light woods. Wood carving has been used in profusion, and this has all been made in Messrs. Denny's own works. It is of an unusually artistic type, and is somewhat remarkable for the method of production. The design is first drawn on the wood by the artist, and all the rough work is executed by electrically-driven "routers." The wood next passes to the skilled artistic carver, and is by him finished. The cost is reduced in this way, while the objectionable stiffness of machine work is entirely avoided.

The propelling machinery consists of two sets of triple-expansion engines. The high pressure cylinders are 23 inches diameter, the intermediate 35½ inches, and the low pressure cylinders 53 inches. The stroke is 33 inches. The engines drive four-bladed propellers, 10 feet diameter, at 155 revolutions per minute. The boiler pressure is 160 pounds. Steam is provided by two double-ended boilers. Fans are provided, sufficiently powerful to give ¾ inch water pressure in the stokeholds, but less than this suffices to keep the pressure.

The boilers are 14 feet 6 inches diameter and 21 feet 1½ inches long, each containing six furnaces, with a total grate surface of 270 square feet; the heating surface is 9,183 square feet.

The whole of the machinery is a very excellent piece of work.

The frames are of carefully selected cast iron, not steel. The condensers are carried high up in the wings on brackets. The shaft tunnels are very roomy. The ship is lighted throughout by electricity, the engines and dynamos being carried on the middle platform, extended under the deck aft for the purpose.

The steering gear is Browne Brothers' patent. The engine is carried on the end of the tiller, and traverses by the aid of a steel-toothed quadrant bolted to the deck. No covering has been provided, the whole of the working gear being inclosed in water-tight casings. Instead of a deck house, there is a rail or fence all round.

For experimental purpose, a run was made from Belfast to Fleetwood, 110 miles, under one engine only, the other screw being allowed to revolve, when a mean speed of 15 knots was attained. On another occasion a steel hawser got wound around the hub of the port screw, and it was deemed inadvisable to allow that screw to turn when making the same run. Its revolution was prevented by putting the port engines in back gear. The ship had then to drag a four-bladed screw through the water, and carry a port helm to keep her head straight. Yet, with all this drawback, she made nearly 13.5 knots.

Seaford.—This twin-screw vessel was mentioned on page 636 of the last number of the JOURNAL, in connection with the *Seine* and *Thames*, built for the London, Brighton and South Coast Railway, and the Western Railway of France. The *Seine* and *Thames* were built in France, and the *Seaford* in Great Britain, by Denny Brothers, Dumbarton, Scotland. Her general design was prepared by Professor Biles, and the contract awarded to Denny Brothers, the requirements being that the mean of the times taken in running from New Haven to Dièppe and return should not be more than 3 hours 15 minutes. On her trial, the actual time required was 3 hours 12 minutes, equivalent to a speed of 20.15 knots.

She is 270 feet long, 34 feet beam, and 14 feet 6 inches deep, and has been fitted with deep bilge keels in order to reduce rolling as much as possible. The engines are of the four-cylinder triple-expansion type, with cylinders 23, 36 and 38 inches diam-

eter (two of the latter), and 27 inches stroke. Steam at 160 pounds pressure is supplied by four single-ended boilers worked under forced draft on the closed fire room system.

Columbia.—A twin-screw steamer similar in size and general construction to the *Seaford*, and built by Messrs. J. and G. Thomson, Clydebank, for the London and Southwestern Company, to run between Havre and Southampton in connection with the transatlantic service of the American Line steamers. She is 270 feet long, 34 feet beam, and has a gross tonnage of 1,150 tons. Her engines are of the four-cylinder triple-expansion type, driving three-bladed screws, which, on a trial of six hours' duration, gave the vessel a speed of about 19½ knots. The boilers are four in number, two forward and two abaft the engines.

She has sleeping accommodations in double-berth state rooms for 100 first-class passengers, and also for 50 second-class.

Knight Bachelor.—A freight steamer recently built by Messrs. Charles Connell & Co., Whitenich, Glasgow. She is 450 feet long between perpendiculars, 52 feet beam, 34 feet deep, of 6,500 tons register, and has a dead weight capacity of 9,000 tons. She has seven water-tight bulkheads, all of which extend to the upper deck, and has a double bottom her entire length, capable of holding 2,200 tons of water ballast. Her engines, built by Dunsmuir & Jackson, Govan, Glasgow, have cylinders 29, 47 and 76 inches diameter by 51 inches stroke, which, on trial, developed 3,400 I.H.P., when working at 880 feet piston speed. Steam, at 175 pounds pressure, is furnished by two six-furnace boilers 15 feet diameter and 17 feet 6 inches long; and there is also a smaller boiler for supplying the auxiliary engines in port. Special attention has been given to the means for rapid loading and unloading, there being seven large hatches, each with a powerful winch. Electric cargo lamps are supplied for night work.

Prinz Heinrich.—A steel twin-screw steamer built by F. Schichau, the torpedo-boat builder, for the North German Lloyd Company, was launched during August. Her dimensions are: Length over all, 445 feet; breadth, 51 feet; depth, 33 feet. She is 6,600 tons register, has accommodation for 80 first-class and 80 second-class passengers and 1,000 emigrants, and is intended for the trade

to China and Australia. Her engines are of the triple-expansion type and are designed for a collective indicated horse-power of 5,000, with which a speed of 15½ knots is expected. They are similar in design to the engines of the Austrian battleship *Tegetthoff*, described on page 421 of the current volume of the JOURNAL.

Banshee.—This paddle-wheel steamer, belonging to the London and Northwestern Railway Company, has recently had her old machinery removed and new triple-expansion engines and high pressure boilers substituted, the work being done by Laird Brothers. The cylinders are placed in line athwartships, the low pressure being in the middle, the high pressure on the port side, and the intermediate on the starboard side. Piston valves are used for the high and intermediate engines, and a balanced D-slide for the low pressure. The reversing gear is attached to the upper framing which supports the guides, and is worked by a steam and hydraulic engine. Steam is generated in six boilers of the locomotive marine type, at a pressure of 155 pounds on the square inch. They are placed in two groups of three each in two closed stokeholds. Air is supplied to the furnaces by two large fans situated on the upper deck, driven by two sets of compound vertical engines. The air pressure is ¾ inch water. The paddle wheels are fitted with curved steel floats of special design.

Her official trial consisted of a run of 96 miles, during which the engines made from 36 to 38 revolutions per minute, giving the vessel a mean speed of 20.42 knots per hour, the I.H.P. being 4,750 and 5,150 for the two rates of revolution of the engines.

The old engines were of the oscillating type, with two cylinders 80 inches in diameter, by 84 inches stroke.

The *Banshee* is 310 feet long, 34 feet beam and 14.4 feet draught.

Prinses Marie.—This paddle steamer belonging to the Zeeland Steam Navigation Company has had Howden's system of forced draft fitted to her boilers, resulting in a marked increase in power and speed. She was built by Elder & Co. in 1878, and is of the following dimensions: Length on water line, 274 feet 8 inches; beam, 34 feet 9 inches; depth, 24 feet 3 inches; draught, 16 feet 5 inches.

Her engines are compound oscillating, with cylinders 60 and 104 inches diameter and 84 inches stroke, working with a steam pressure of 80 pounds per square inch. Her boilers are four in number, single-ended, 15 feet 7½ inches in diameter and 9 feet 1 inch long, and originally contained 365 square feet of grate surface. When the Howden system of draft was fitted, the grate was reduced in length from 6 feet 8 inches to 5 feet 3 inches, reducing the grate surface to 287 square feet. The heating surface is 7,304 square feet.

Before fitting this system of forced draft, the I.H.P. was about 3,500, and on her trial after the alteration was made 4,600 I.H.P. was maintained without any trouble.

YACHTS.

La Belle Sauvage.—A steel, auxiliary three-masted steam yacht, was launched from the yard of Messrs. Ramage and Ferguson on the first of October. She is from designs by Mr. G. L. Watson, of 755 tons yacht measurement, and is intended for extensive foreign cruising; has been built to the highest class at Lloyds, with several important additions to her strength in excess of their requirements, and her equipment is in all respects of an unusually complete description. The principal dimensions are: Length over all, 190 feet; breadth, 29 feet, and depth, 18 feet; and the machinery, of the builders' special design, consists of a set of triple-expansion engines of 700 I.H.P., having cylinders 14 inches, 23 inches and 36 inches diameter by 27 inches stroke. Steam is supplied to the engines by a Belleville boiler. A telescopic funnel and patent Bevis feathering propeller enable those on board to quickly adapt the yacht for proceeding under sail alone; and for assisting in the handling of the sheets and halyards, steam capstans are placed fore and aft. The accommodation below is commodious, and is fitted up in a most luxurious style, and on deck there is an unusually large deckhouse for an auxiliary yacht. On leaving the ways the yacht was named *La Belle Sauvage.*

This is probably the same unnamed yacht whose dimensions were given on page 442 of the current volume.

Messrs. C. L. Seabury & Co. are busy at their works at Nyack, with two yachts, one for Mr. F. C. Fowler, of Moodus, Conn., length over all, 120 feet; load water line, 97 feet; beam, 16 feet; depth, 9 feet; draught, 6 feet 6 inches. The yacht is to be composite build, viz: Steel frames, deck timbers, keelsons, etc., and wood planking in two thicknesses of yellow pine. The yacht is to be flush deck, schooner rigged, with a mahogany house on deck 16 feet long, to be used as a dining room, with bridge to steer from over head. The accommodations will be first-class. She will have two guests' staterooms, one with single berth and one with double berth. The owner's stateroom will be 6½ feet

long, and extend the full width of the vessel, with bath tub, water closet, wash basin, and dressing case on one side in separate compartment, connecting with stateroom. There will be a fine large saloon with seats arranged as berths, large galley, captain's room, crew's quarters, crew's toilet room, lazerette, etc. The yacht will be first-class in her appointments throughout, and will have everything aboard of her up to date. She will be thoroughly modern in every way. The machinery will consist of a Seabury triple-expansion engine and two Seabury patent safety water-tube boilers of latest design, which will develop sufficient power to drive her at a guaranteed speed of 15 miles per hour for three consecutive hours over a measured course. She will carry an 18-foot gig, an 18-foot launch, a 15-foot cutter and a 14-foot dinghey. She will be completed and ready for delivery by June 1, 1895. The second yacht is for a New York yachtsman. Length over all, 65 feet; load water line, 52 feet; beam, 11 feet; draught, 4 feet. This yacht will be built of wood. Oak keel, frames, stem post, stern post and deadwood of oak; yellow pine and white cedar planking, white pine decks. She will be schooner rigged, and will have a low trunk cabin house, with a 7-foot pilot house, all to be constructed of mahogany finished bright, natural color; the inside finished in panel work, with tinted enamel and gold, china gloss. Forward will be arranged crew's quarters. Next aft will be the pilot house; aft of that will be owner's saloon, with toilet room on one side in separate compartment; engine and boiler room next aft; next aft is galley on port side and a toilet room on opposite side, fitted with water closet, set wash basin, towel rack, mirror, etc. Aft of these compartments is arranged the after saloon, which is fitted with transoms, arranged to sleep one on each side, wine locker, china locker, etc.; this room is finished in tinted enamel and gold, china gloss. There will be nice deck on either side of house, also deck forward and aft. The machinery will consist of a Seabury triple-expansion engine and a Seabury patent safety water-tube boiler. The speed is 12 miles per hour. The yacht will be ready for delivery by May 1, 1895.—(From "Forest and Stream.").

BOOK REVIEWS.

ARCHITECTURE NAVALE. PRACTICAL CONSTRUCTION OF SHIPS OF WAR. VOLUME I.—BY A. CRONEAU, NAVAL CONSTRUCTOR, FRENCH NAVY, PROFESSOR OF NAVAL ARCHITECTURE AT THE FRENCH NATIONAL SCHOOL OF NAVAL ENGINEERING AT PARIS.

There are so few works on practical naval architecture, and, on account of rapid changes, they are so far from modern, that this work, representing the latest practice in steel warship construction, will be very acceptable to those interested in this branch of engineering. Moreover, being wholly confined to the consideration of ships of war, it is more complete than any other work hitherto produced. The first volume contains 360 pages.

Mr. Croneau begins with a general description of a warship, defining the technical terms used in connection with its construction. Then follows a very good general description of the methods of laying down and fairing a set of lines in the draughting room, and the French methods of measurement and calculations for displacement.

A chapter is devoted to mould loft methods, and another to materials used in construction, the latter containing the practical part only of the strength of materials, and tables of the properties and requirements of steel for warship work.

The subject of rivets and riveted joints, their forms, and the different methods of assembling in ship work, the structural strength of certain forms of joints, followed by a good summary of the mathematical theory of the strength of riveted joints, and finally the application of formulæ, the whole covering over 60 pages, forms one of the most noticeable and interesting features of the book.

The author next defines the different classes into which he considers warships divided, describing the peculiar service to which each is adapted. The classes into which they naturally

divide themselves according to the materials or methods used in their construction is also considered.

The remainder of the volume, about 200 pages, is occupied with a detailed description of the construction of the various classes of vessels: Battle-ships, coast-guard vessels, armored gun-boats, rams, cruisers, with and without a double bottom, protected and armored, dispatch vessels for distant service (composite), torpedo-vessels, gun boats for distant service (sheathed), transports and mail packets. Here are discussed the differences between the methods of construction followed by different nations in vessels of the same type, and all details of construction are considered as relate to framing (transverse and longitudinal), decks, double-bottom, armor, armored decks, superstructures, stems and stern posts, outside plating, ceiling, plating behind armor, and planking of composite and sheathed vessels.

The volume contains numerous figures and sketches to illustrate the discussions, and in addition, is accompanied by a book of large plates, in which are shown general plans of sixteen typical war ships, and also complete plans of the ventilation, drainage and water-service systems of typical French and English battle-ships.

For the first time, in a foreign work of this kind, American war-ships appear to a considerable extent, for illustration and description, alongside of vessels of the French, English, German and Italian navies.

Considering the reputation and position of its author, the work is of the highest authority.

PRAY'S STEAM TABLES AND ENGINE CONSTANTS.—By Thomas Pray, Jr.: New York, D. Van Nostrand Co. Price, $2.

As its title indicates, this book contains tables of the properties of steam, tog ether with hyperbolic logs, engine constants etc., covering 65 pages, and the purpose of the author has been to put under one cover all the important elements required in steam engine testing work. The tables are preceded by 34 pages of explanatory matter, in which examples are worked out, to illustrate the purpose of each table. It is to be regretted, how-

ever, that this part of the work bears the marks of hurried preparation or of careless proof reading, as in works of this kind one's impressions of the value of the tables, which, in this case, are said to have all been calculated from the original results by Regnault and Rankine, is apt to be judged by the correctness of the explanatory matter. Aside from the evident hurried preparation of this part of the work, there is no reason to doubt the accuracy of the figures in the tables, which the author says have been checked, in order to avoid error. The book is in convenient form, and the tables should be of great value as a "time saver" to any one engaged in experimental or testing work.